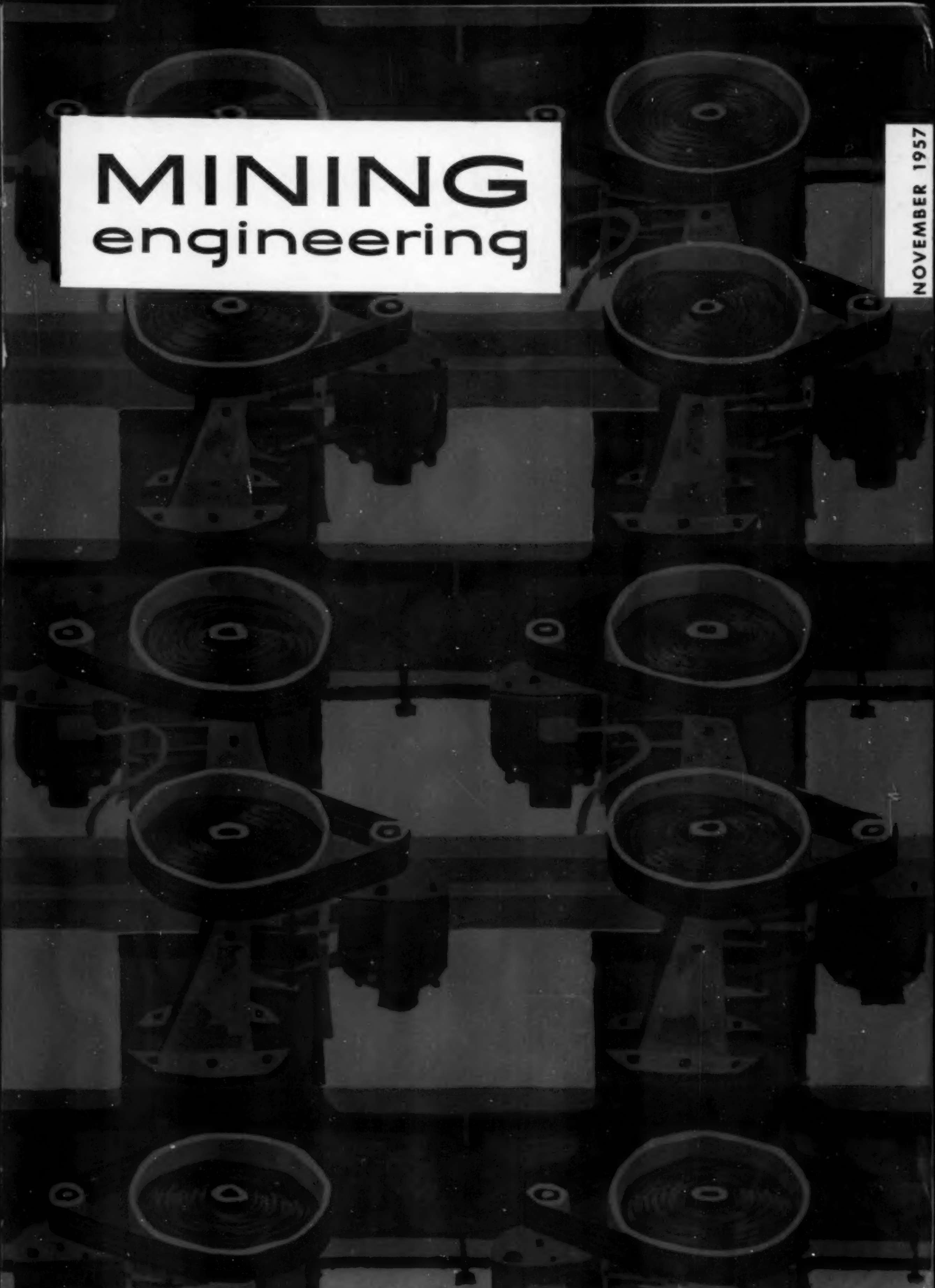
MINING engineering

NOVEMBER 1957



The AIME also publishes **Journal of Metals** and **Journal of Petroleum Technology**

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MINING engineering

VOL. 9 NO. 11 NOVEMBER 1957

COVER

Banks of flotation cells were chosen by cover artist Herb McClure to illustrate this unit operation. Detailed descriptions of the units as used for treatment of low grade porphyry copper ore from the Lavender open pit are given on page 1229.

News of Your Society

ARTICLES

TRANSACTIONS

FEATURES

PERSONNEL

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6c in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Executive, B. S. in mining engineering, age 37. Eleven years diversified underground mining experience, primarily in operations. Location, immaterial. M-363.

Project Engineer-Chief Engineer, B. S. in geology, M. S. in mining, age 36. Several years experience engineering and design of placer and open pit properties. Familiar with gravity beneficiation equipment and magnetic, electrostatic separators and plants. Prefer U. S., will accept foreign. M-364.

Mining Engineer-Geologist, 48, married, one child. Perfect physical condition. Twenty-five years experience all types underground mining; ample administrative experience and ability. Thoroughly experienced geologic examinations, valuation, reports. Fluent Spanish and French, permanent Mexican passport. Location, immaterial, but Latin America preferred. Employed; available reasonable notice. M-365.

Mining Engineer, A.C.S.M. degree, age 35. Eleven years open pit experience, junior engineer, shift foreman, last three years as mine superintendent. Prefer Southwest. M-366.

Geologist, B.S., age 30. Four years experience minerals, exploration and development covering iron ore and industrial clays; drilling, strip mining, and milling. General and executive management. Location, immaterial. M-368.

Geologist, 42, B.S. and M.S., experience in exploration and mining geology, metallic and nonmetallic mineral deposits of many types including placers. Considerable administrative experience. Now employed by United Nations in Far East. Seeking position with growing company engaged in active exploration and development of diversified mineral deposits. Western U. S. preferred but will consider other locale if job is right. Available early 1958. M-369.

Geologist, B.S. and M.S., age 55, economic geology, 12 years; petroleum geology, 4 years; chemical engineering, 5 years; mineral technology, 2 years; teaching geology, 3 years. Qualified for work on metallic deposits, oil and gas exploration, water studies, and engineering geology. Prefer foreign location. M-370.

POSITIONS OPEN

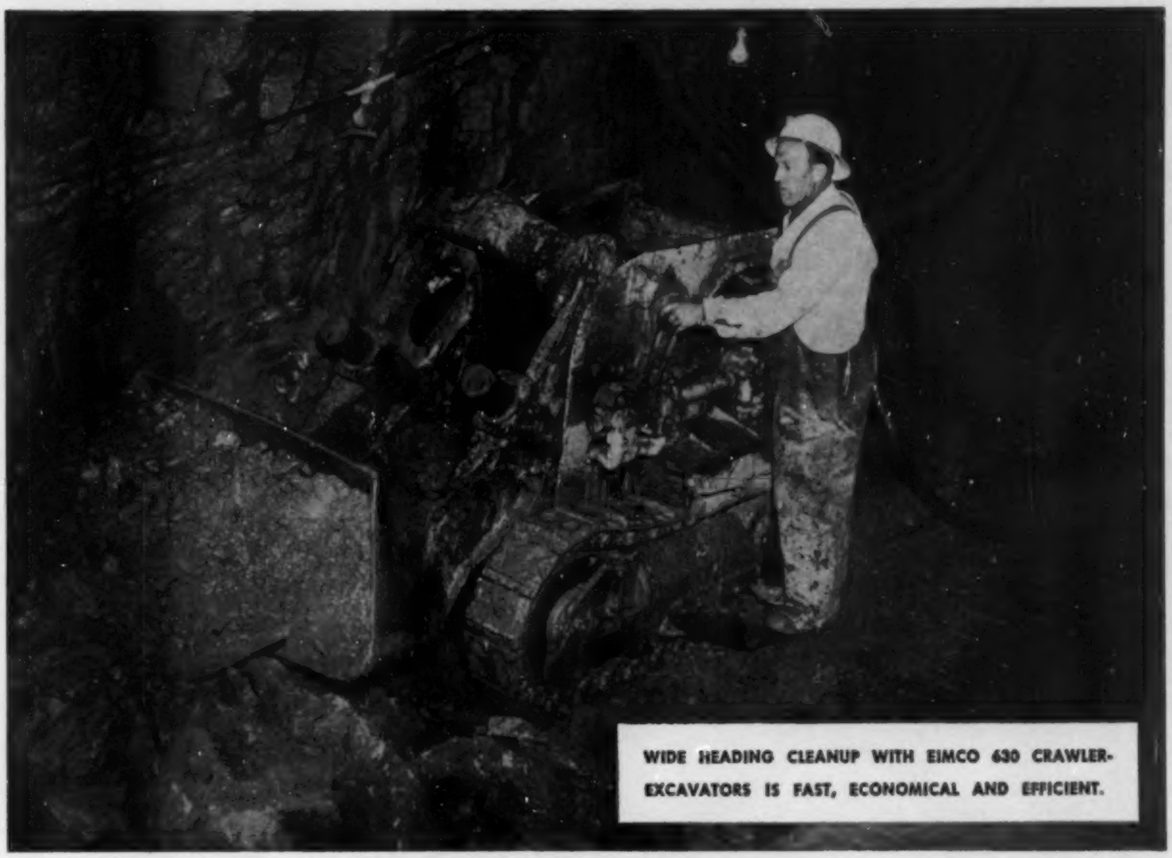
Sales Engineer, young, with engineering training and some mining experience, for sales and service work covering rock drills. Salary, $6000 a year plus bonus. Location, New York, W5417.

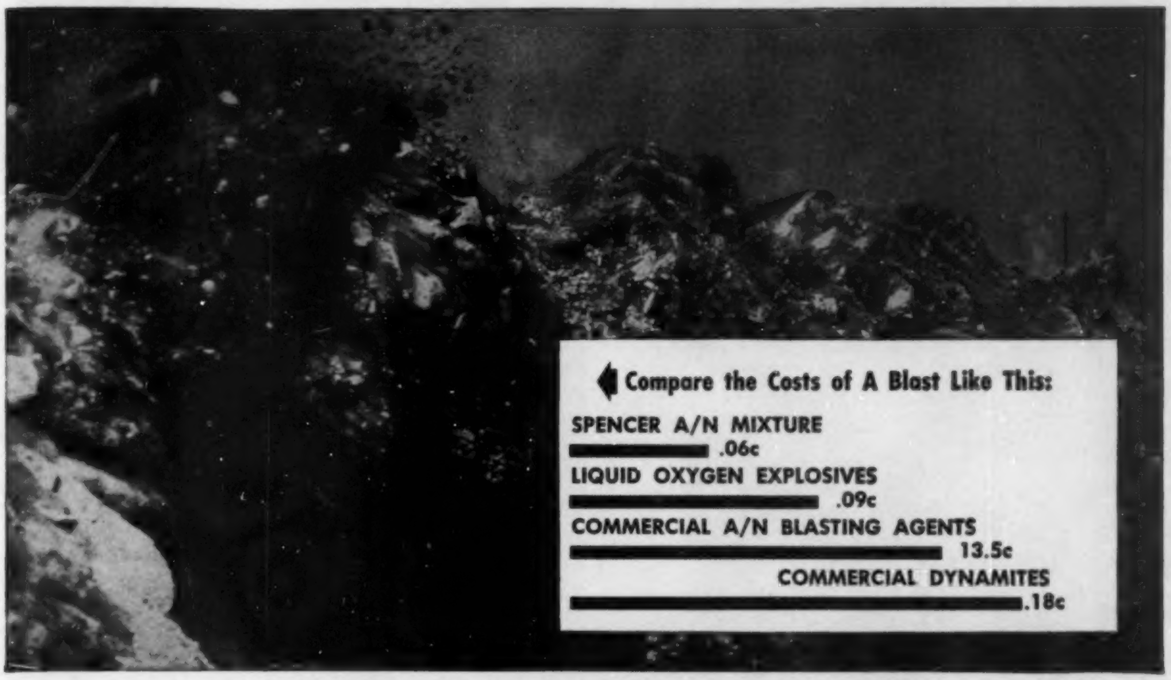
Mining Engineers, to go abroad to improve operation of an existing open-cut copper mine and to set up a new open-cut mine on a similar deposit. Recent experience in this type of work, presumably in southwestern U. S. or in the Andes. Location, Europe. F5362.

Assistant Manager, mining or metallurgical engineering graduate, with at least 15 years metal and milling experience. Salary, about $10,000 a year. Location, East. W5353.

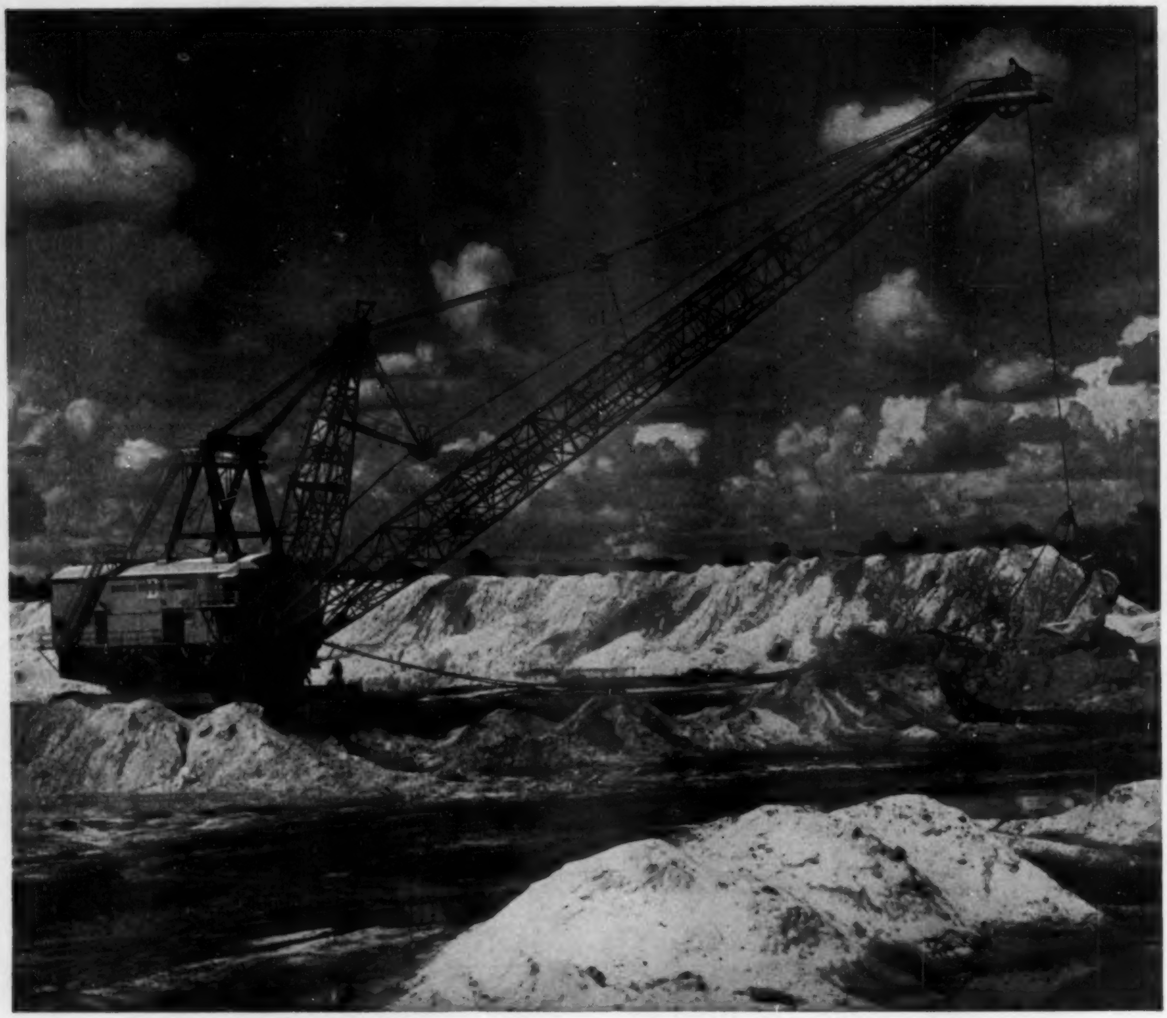
General Mine Foreman, for lead-zinc mine. Good foundation in underground mining methods and ex-

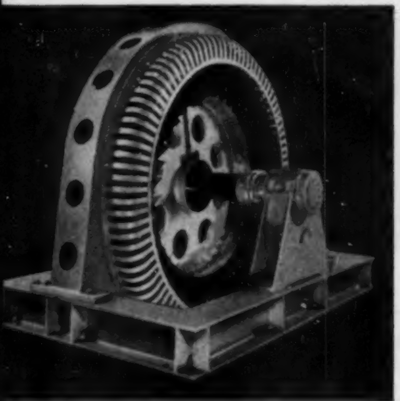
(Continued on page 1202)

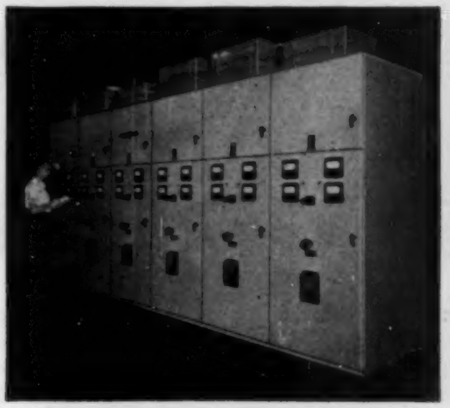




YOU CAN CUT BLASTING COSTS UP TO 50% with new ammonium nitrate blasting process pioneered by Spencer Chemical Company and Maumee Collieries.







Another Mining Company

This is a new important mining operation that is taking advantage of the cost saving benefits made possible by the Gismo Self-Loading Transport. The Jefferson City Mine of The New Jersey Zinc Company is an example of the result that can be obtained by careful planning, design and selection of equipment.

This Gismo machine makes it possible for you to devise and organize a simple mining method. We believe the lowest cost possible is obtained when your plan provides for the fewest pieces of equipment, supplies and men. The Gismo is simple, versatile — mucks in development or production, can drill as a jumbo, make its own roadways, etc. It can transfer its load direct to cars by means of ramp cars . . . or direct to cars or trucks by means of ramping-over (see circled photo at right) . . . or direct to surge pocket for transfer to a common haulage system or method.

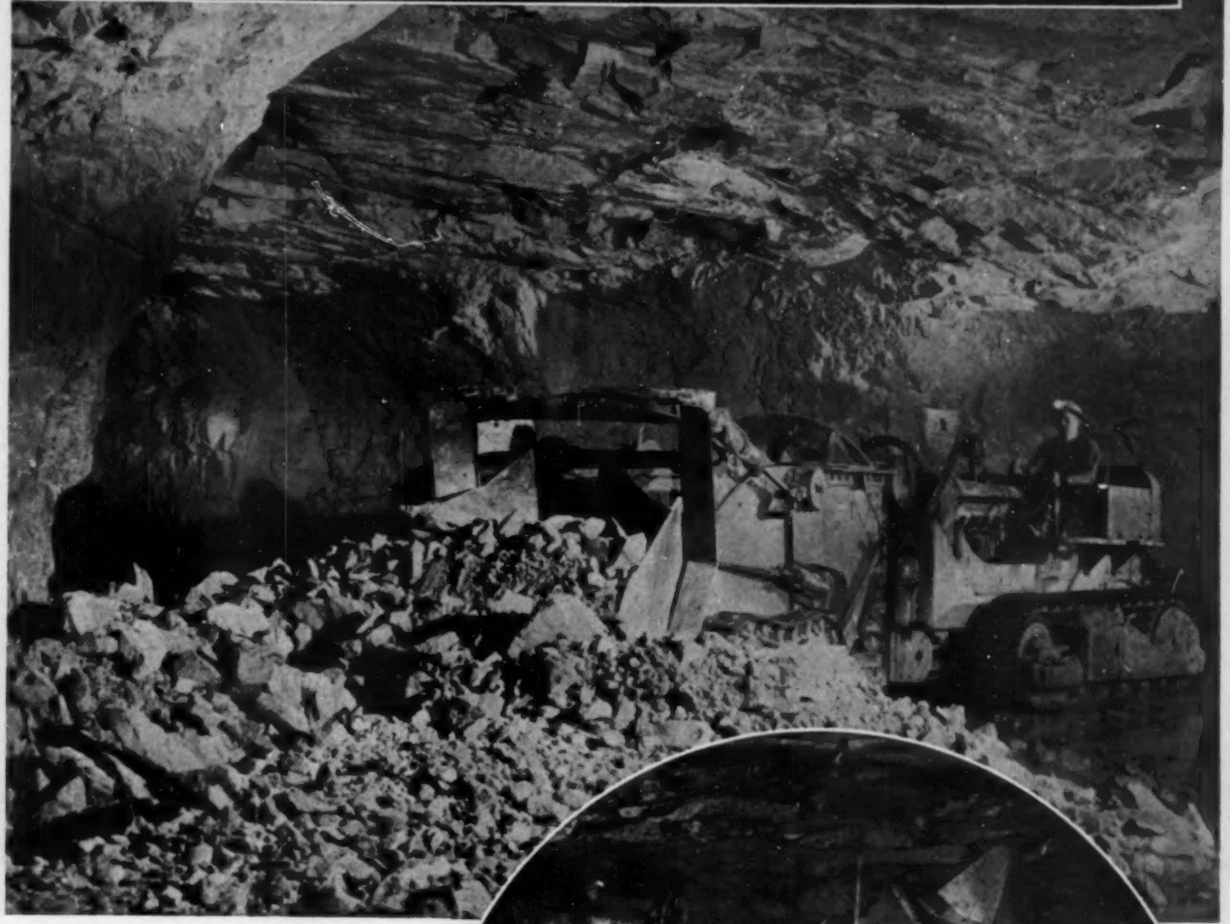
Investigate the extraordinary economies that have been obtained with the use of this remarkable machine. Its principle provides you with a new fundamental opportunity to devise ways and means of cutting costs that you have not had for many years. Write us today. Sanford-Day Iron Works, Inc., Knoxville, Tenn.

SANFORD-DAY

KNOXVILLE, TENNESSEE

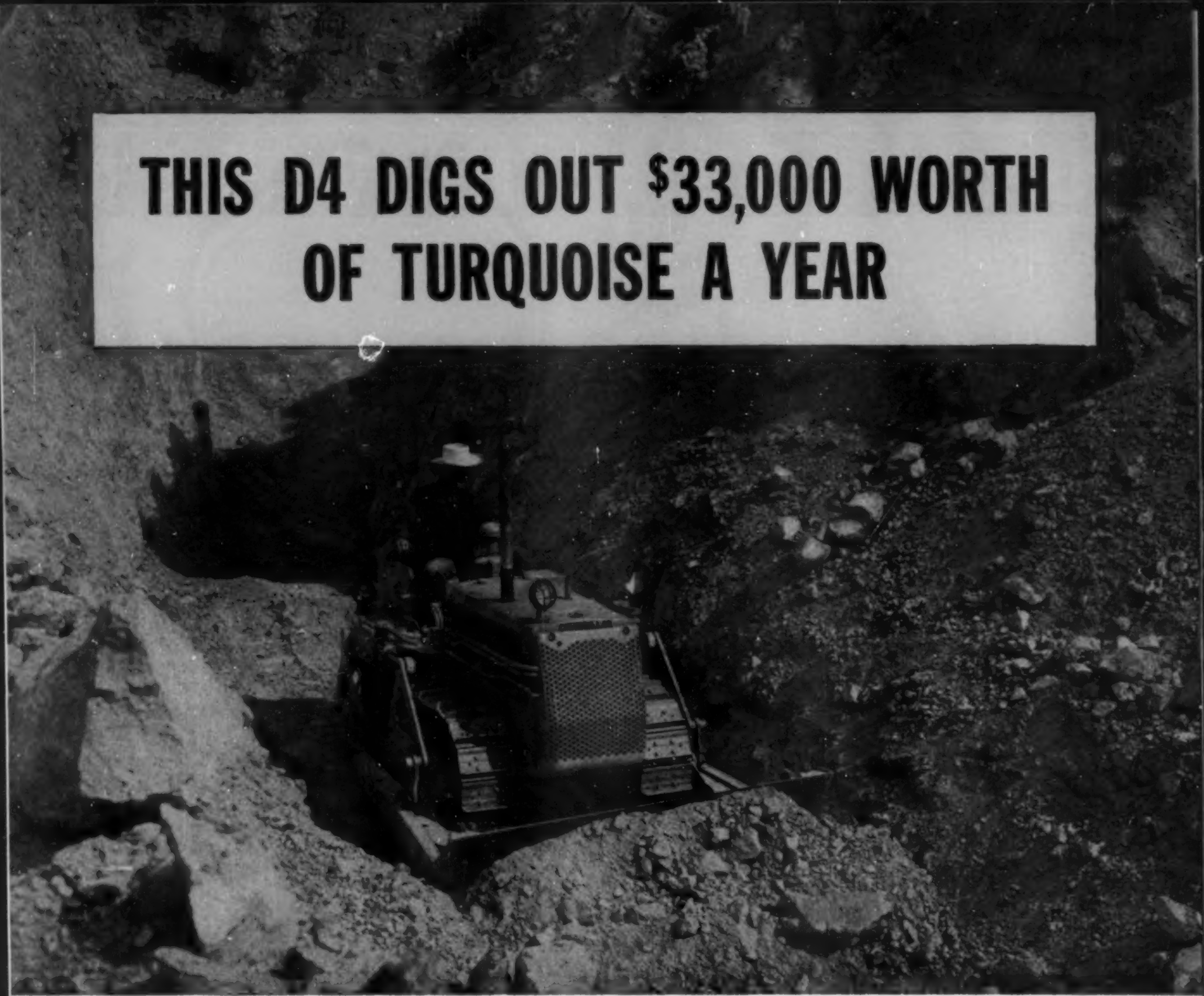
SUPER MARKET FOR MINE CARS — all types . . . PRECISION WHEELS . . . BROWNIE HOISTS . . . GISMO SELF-LOADING TRANSPORT that loads in development or production . . . transports . . . supports 2 to 5 jib mounted drills . . . back fills . . . moves boulder rocks . . . makes its own roadways and cleans up completely — a new method of hard rock mining offering a tremendous reduction in cost per ton!

Puts the Gismo® to Work!



THE NEW JERSEY ZINC COMPANY'S Jefferson City Mine incorporates the latest and most modern equipment, including the Gismo, S-D Ore Cars and S-D "Brownie" Hoist. Above you see the Gismo mucking out a load. Circled photo at right shows the ramp-over-cars' transfer point. One man, the Gismo operator, handles the entire operation by means of push-button control of the S-D "Brownie" Hoist. Operator's control lever is located just below roof above the ramp. The S-D "Brownie" Hoist automatically moves trip when another empty car is positioned under ramp. Operating arm located beside cars "tells" hoist when to stop the trip. The S-D Ore Cars haul production to ore pass.

THIS D4 DIGS OUT $33,000 WORTH OF TURQUOISE A YEAR



You're looking at some of the richest rock in Colorado. Here, northwest of Villa Grove, gem turquoise comes out in chunks valued from $30 to $150 a pound. To get it, the Villa Grove Turquoise Lode Co. uses this husky Caterpillar D4 Tractor with No. 4A 'Dozer.

On a good day this D4 'dozes a hundred tons of rock and overburden and moves them a distance of some 200 feet. Last year it carved out over $33,000 worth of turquoise.

Owner M. C. Winfield chose the CAT* D4 Tractor for this job because he liked its power. There's 50 drawbar HP in this machine, with a maximum drawbar pull of 10,700 pounds. There's sturdy quality built into every inch, from the long-life track pins and heavy-duty track rollers all the way into the rugged, dependable transmission. And Caterpillar's famed oil clutch, job-proven by thousands of hours of hard-working service, is available now on the D4.

Other important features include an exclusive all-weather starting engine (it gets mighty cold up in this Colorado country!) and a fuel injection system that squeezes power from every drop of low-cost, non-premium fuel.

Your Caterpillar Dealer will be happy to demonstrate the D4—or any other of his big yellow machines—right out on your job. He's the man to call for expert service, too, and for replacement parts you can trust.

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

CATERPILLAR*

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

NAME THE DATE... YOUR DEALER WILL DEMONSTRATE

Manufacturers News

News
Equipment
Catalogs

• FILL OUT THE CARD FOR MORE INFORMATION •

Shaft Mounted Drives

Falk Corp. has added a higher ratio of 24:1 to its line of double reduction drives, keeping the same outside dimensions and torque rating. Practical advantages of the new shaft mounted drives include use of smaller sheaves to attain a given output speed and a saving in motor cost. Expensive low speed motors are not necessary. The drives are available for horizontal and vertical use in a range from ½ to 30 hp, with output speeds as low as 5 rpm. **Circle No. 1.**

Ammonium Nitrate Blasting

Ammonium nitrate fertilizer costs 3½¢ a lb while conventional blasting agents cost from 8¢ a lb upward. Add this to the fact that it is extremely safe to handle and can be controlled by experienced men, says *Monsanto Chemical Co.*, and you have the reasons why more quarry men and strip coal mine operators are using ammonium nitrate for blasting needs. Before the agent can be used, it must be correctly mixed with fuel oil, confined, and detonated by dynamite charge. **Circle No. 2.**

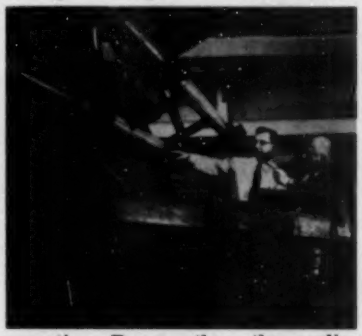
Material Level Control

Bin-Dicator Co. has announced an improved model of the Roto-Bin-Dicator, a unit which automatically maintains the level of bulk material in bins, chutes, conveyors. The new control features improved low torque motor, gear reduction unit, and

mounting arrangement. New optional single-vane paddles and large 4-vane paddles are offered. Installation is simple, requiring only a hole in the bin wall to admit the paddle, attachment of a steel plate with six screws, and connection to a power source. **Circle No. 3.**

Flying Cup

The new Flying Cup, manufactured by *Dwight-Lloyd Div.*, McDowell Co. Inc., combines mixing and pelletizing in one continuous



operation. Deeper than the earlier Flying Saucer, it produces pellets up to 1½-in. diam, depending on angle of tilt and rotation speed. Machines can be of any capacity. **Circle No. 4.**

Ore Haulers

The first of the new Kenworth 803-B's will be used to carry iron ore for the Eagle Mountain mine of Kaiser Steel Corp. These rear dumpers by *Kenworth Motor Truck Co.* have a rated payload of 64 tons or 40 cu yd struck. Rugged body is

all-welded. A body guide and equalizer provide stability during dumping. Powered by a 12-cyl diesel engine, the truck will be offered as a 400 or 600-hp unit. Gross weight is rated at 228,000 lb. **Circle No. 5.**

Protecting Storage Piles

A spray from *Johnson-March Corp.* will protect outdoor storage piles of bulk materials against all types of weather conditions for about a year. Called Permaspray, the product is a colloidal suspension in water which, when exposed to air, forms a tough, flexible, water-resistant film. Treated areas are said to resist the action of wind, rain, frost, and heat. When the surface film is broken the area can be redressed and another coating applied. One gallon is sufficient for 100-sq ft surface. **Circle No. 6.**

Compact Sampler

New, compact Vezin-type sampler housed in dust-tight metal-sheet cylinder is offered by *Denver Equipment Co.* in 20, 24, 28, 36, 48, and 60-in. simplex, duplex, or multiple sampling units. Attached to continuously revolving vertical cylinder inside, one or more radial cutters take samples from discharge end of feed chute. Samples go by pipe or chute to units for reduction or further preparation. **Circle No. 7.**

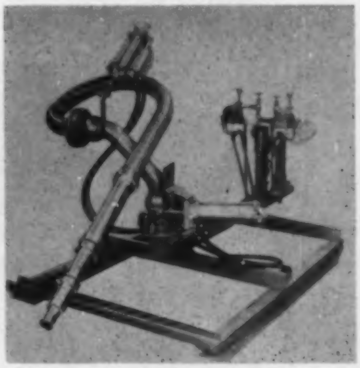
Loading Equipment

Joy Mfg. Co.'s new JSL-7 shovel loaders, JMD-7 mining dozers, and JMT-7 mining tractors come with air or electric drive. Independent track

control permits turning within machine radius. The mining tractor also serves as base for loader, mining dozer, and other attachments. **Circle No. 8.**

Hydraulic Monitor

Smallest of the *Chiksan Co.* Intelli-Giant hydraulic monitors is this new 3-in. model which may be used for removal of permafrost, overburden, and in slurrying. Unit has a 270° horizontal traverse and 120° vertical sweep. Hydraulic controls are powered by water pressure; for cold weather a closed-circuit system is available. **Circle No. 9.**



News & Notes

American Cyanamid Co. has acquired the assets and business of the Illinois Powder Mfg. Co., including plants in Grafton, Ill., and Gomex, Utah, and more than 50 magazines in 24 states.

(21) HARD-FACING ELECTRODES: A new 8-page electrode booklet is available from *Haynes Stellite Co.*, division of Union Carbide Corp. The brochure covers the chemical composition, some properties, typical applications, application procedures, and packaging for the 12 Haynes electrode alloys. These include eight iron-base alloys, three cobalt-base alloys, and Haystellite cast tungsten carbide.

(22) WOBBLER FEEDER: The Universal Wobbler Feeder is now available in lengths from 4 to 18 ft. Widths are available from 24 to 72 in. Number of feeder bars varies from ten to 16 and these are available in carbon steel, silico-manganese or manganese steel. Capacities vary from 15 to 1000 tph or more depending on the type of material and per cent of fines to be removed. The Wobbler Feeder is available in 7½ to 25 hp sizes. More detailed information can be obtained from the *Universal Engineering Corp.*

(23) GEAR PUMP: A reversible sealed gear pump of compact design (2½-in. diam) is now being offered by the *Bijur Lubricating Corp.* Pump is designed to be driven from a rotating machine shaft either directly or through a gear chain drive of suitable ratio, and is applicable to machine tools or any other machine requiring "flood lubrication" over gear trains, chains, or cams. Special features include a lip-style seal, a built-in relief valve, and the reversal of drive direction while maintaining the same direction of oil flow. Modifications are available.

(24) COMPANY PRODUCTS: *Universal Engineering Corp.* has published a new condensed catalog on its product line. The 20-page brochure gives specifications and illustrations of the company's line of crushing, screening, washing, loading, feeding, and conveying equipment produced for the mining, quarrying, and aggregate industries.

Free Literature

(25) AMMONIA: The Nitrogen Div. of *Allied Chemical & Dye Corp.* has recently put out a new 68-page technical data book on anhydrous ammonia and ammonia liquor. The book lists their chemical and physical properties, specifications, handling and storage features, unloading methods, analytical procedures, and a bibliography. Graphic illustrations include data pertaining to viscosities, density, vapor pressures, boiling and freezing points and other characteristics.

(26) SOLENOID VALVES: A completely new ASCO solenoid valve catalogue, having 114 pages with 8 indexed sections, is now available from the *Automatic Switch Co.* The new catalog's indexed sections are composed of the following: engineering information; 2, 3, and 4-way solenoid valves; manual reset 2 and 3-way valves; corrosion resistant valves and selection guide; and special purpose valves and accessories. A general index and selection guide, as well as a quick index, are provided for locating a valve for a particular application. The catalog also contains construction details, flow diagrams, cross section views, prices.

(27) ROTARY COMPRESSOR: The Model 125 rotary compressor is shown in *Davey Compressor Co.'s* new bulletin, complete with unit illustrations, complete specifications, and a rotary compression cycle diagram. The model features multiple stage rotary compression, fewer working parts, continuous cooling, more air per lb of fuel, and vibration free operation. Model 125 is completely rainproof and can be locked against theft or vandalism.

(28) ELECTRODE GUIDE: Information essential to anyone concerned with buying or using electrodes is now available in a new 70-page booklet from *Air Reduction Sales Co.* The guide describes each Airco electrode, its color code, application, and best welding procedure. Other helpful features included in the booklet are an electrode consumption calculator and related information on electrode selection, industrial and government specifications for filler metals, and testing of deposited weld metal.

(29) STEEL TUBE: *Ohio Seamless Tube Div.*, Copperweld Steel Co., has released a 12-page booklet, IA-6, depicting some of the many uses of seamless and electric-resistance welded steel tubing in materials handling equipment. Of interest to design engineers, purchasing agents and others in metal working plants, the content is suggestive of similar steel tube applications in many other fields.

(30) SAFETY DATA: *National Safety Council* offers an order form covering a large selection of safety data sheets on all phases of industry. They are available at nominal cost. Among those of interest in the mining field are: Jackhammers in Quarries, Safety in Scraping Operations, Drilling in Mines, Detecting Loose Rock, Stray Currents in Electric Blasting. Bound sets are also offered covering general industry, special industry, and chemicals.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

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Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after Feb. 15, 1958—if mailed in U. S. or Canada

Please send { More Information ☐ / Price Data ☐ / Free Literature ☐ } on items circled.

Name————————————Title————

Company————————————

Street————————————

City and Zone————————————State————

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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	Students should write direct to manufacturer.					

(31) LITHIUM: A monthly newsletter published by the *American Lithium Institute* is available to management, technical, and production people of industries where lithium has found application or might be applied in the future. The newsletter, "What's New With Lithium," will include a review of new developments in the field of lithium as well as a summary of current articles in trade and business publications.

(32) CYCLONES: Installation photos and performance data on many diversified applications of the Krebs cyclones is now offered in 16-page Bulletin 830 from *Equipment Engineers Co.* Krebs now has 17 models that range in size from the huge Model D30 to a 3-in. model. Advance design features and a variety of applications make for peak performance.

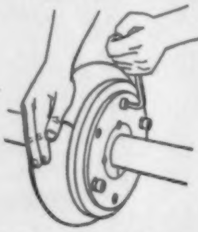
(33) MOTOR SCRAPER: Design and performance of the TS-160 motor scraper, recently added to the *Allis-Chalmers* line, are highlighted in new 8-page Catalog MS-1226. Booklet is offered by the Construction Eqpt. Div.

(34) SHOP TALK: A new 8-page booklet stressing preventative maintenance has been released by *Caterpillar Tractor Co.* It describes the dealer's role in supplying prompt parts and service to machine owners.

(35) DUST DISTRIBUTOR: *Mine Safety Appliances Co.* offers Bulletin 1201-4, which describes a portable machine for discharging a mixture of rock dust and water in bituminous coal mines for on-shift rock dusting. Known as the M-S-A Slurry Rock Dust Distributor, it is capable of dusting 80 lineal ft of mine entry with one 40 lb batch of slurry. Up to 600 ft of hose length can be used with the machine, which comes equipped with an explosion tested motor and control of any needed voltage.

(36) DIESEL POWER: *International Harvester Co.* has published a 12-page catalog covering its line of six diesel power units which range from 60 to 76 hp in 4-cyl sizes, and from 115 to 200 hp on the more powerful 6-cyl units. Featured are diagrams, cross sections, exploded views, and photo close-ups. Desirable design features are explained pictorially, and hp ratings, dimensions, and adaptability of the units are covered.

(37) FLEXIBLE COUPLING: Ability to handle angular misalignment, parallel misalignment, and end float is one of the advantages of the new Paraflex coupling by *Dodge Mfg. Corp.* The flexible member also cush-



ions shock loads and diminishes torsional vibration. Heart of the coupling is a tire with synthetic tension members bonded in rubber. It is available in capacities up to 600 hp at 900 rpm.

(38) DUST CONTROL: An illustrated piece of literature explaining the economies of dust control has been issued by *Torit Mfg. Co.* Booklet shows how Torit-designed unitized dust collectors reduce capital expenditure, operating time, and machine operating costs, and increase employe efficiency. On-the-job photos and application stories demonstrate typical installations of both cabinet cloth filter dust collectors and cyclone separator type collectors. Also discussed is a new diamond collector which has recovered as much as $125 worth of diamond chips in 13 days of test operation.

(39) EARTHMOVING: A 16-page catalog, virtually covering the entire IH mobile construction equipment line from mining to farming, is offered by *International Harvester Co.* Among others are shown crawler tractors, Payscraper units, International Drott Skid-Shovels and 4-in-1 units, and Payhauler units. This illustrated reference guide is entitled "Earthmoving Equipment," Catalog CR-542-G.

(40) V-BELTING: *Boston Woven Hose & Rubber Co.* offers new descriptive literature explaining uses, advantages, and specifications of its line of Boston Bull Dog roll lot V-belting. Detailed specifications and data include equivalent length tables for endless V-belting replacements. Reduced down time costs in V-belt drive breakdowns is the feature offered by Bull Dog V-belting.

(41) DIESEL: Bulletin 111 offered by *White Diesel Engine Div.*, White Motor Co., features the Model 65 Superior stationary diesel. Listed in the 8-page brochure are typical applications, product photos, construction feature illustrations, specifications, and performance curves. Model 65's are built as 4-cycle, 6 or 8-cyl, vertical, in-line engines. Power range is 580 to 2150 bhp continuous. Engines are used with generators of 400 to 1500 kw.

(42) AIR COMPRESSORS: *Le Roi Div.* of Westinghouse Air Brake Co. has issued three new pieces of literature depicting the entire line of Westinghouse unit type and Le Roi stationary air compressors. Compressors described range in size from ½ to 100 hp and include both single and two-stage units. Featured in the two-color folders are lubrication systems, automatic protections, volumes and pressures. Products are illustrated with photos and drawings.

(43) CONVEYORS: "Keep material moving" is the theme of a compact 36-page conveyor catalog published by *Pioneer Engineering.* Described are the two lines of job-engineered conveyors and pre-engineered (packaged) conveyors manufactured by Pioneer. Much attention has been given to accessory items such as drive tapes, head and tail sections, supports, rock ladders, troughing and support idlers, belt take-ups, hoppers. Catalog includes a visual indexing system.

(44) ANTIFOAM: A factual information sheet describing the properties and uses of Hodag Antifoam S-118 is offered by *Hodag Chemical Corp.* Antifoam S-118 is designed especially for industrial waste treatment plants to prevent the formation of foam. It is a free flowing liquid which can be applied either manually or through the use of automatic systems.

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New York, N. Y.

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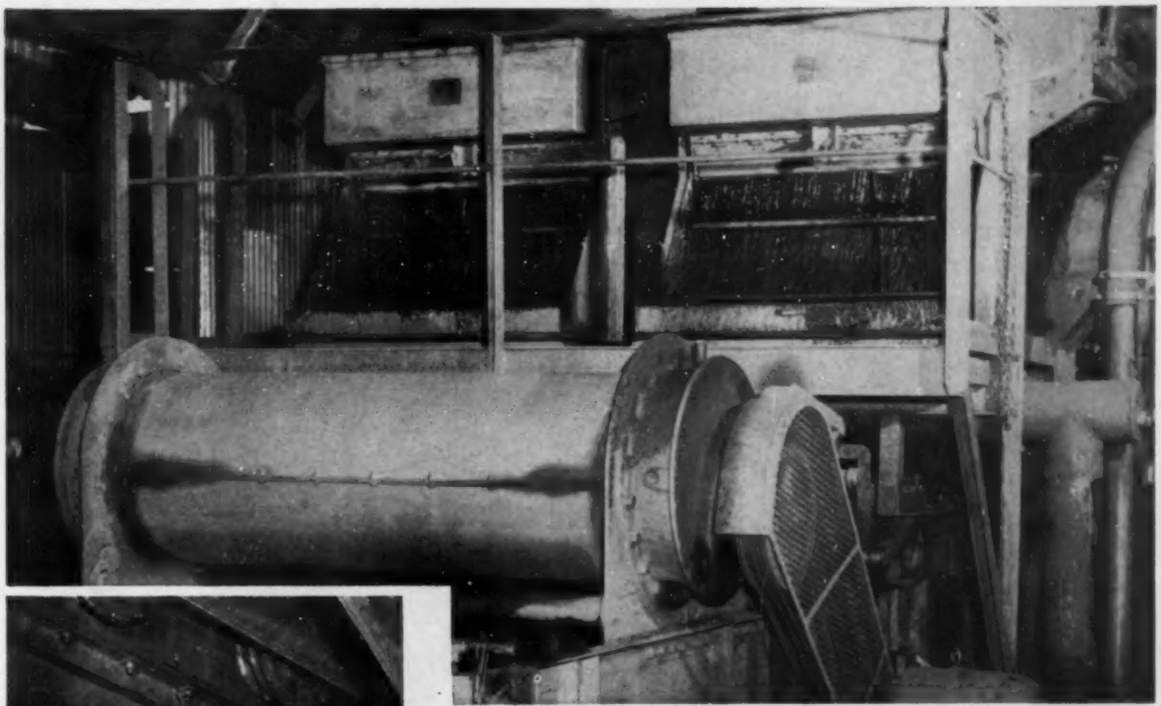


Rear view of unit, note total utilization of entire screen area.

BOOKS

Manual on Rock Blasting, *Atlas Copco Eastern Inc.*, 151 Linwood Ave., Paterson, N. J., and *Atlas Pacific Inc.*, 930 Brittan Ave., San Carlos, Calif., $2.50, 1957—This fifth supplement to the Manual deals with the construction and operation of percussion rock drills, and the applications of diamond drilling. The Manual and five supplements, complete, are available from Atlas Copco (addresses above) for $31.50.

Subsurface Dolomite and Limestone Resources of Grundy and Kendall Counties, by Meredith E. Ostrom, *Illinois State Geological Survey*, Urbana, Ill., 25 pp., 1957—This report was prepared in response to increasing interest in shallow dolomite and limestone resources in the counties neighboring the Chicago area. The resources, especially those not exposed at the surface, are indicated on maps (based on well data and outcrops) that show the distribution of the bedrock formations, depth to dolomite or dolomite limestone, and thickness.

Gypsum And Anhydrite In Illinois, by Donold B. Saxby and J. E. Lamar, Circular 226, *Illinois State Geological Survey*, Urbana, Ill., 26 pp., 1957—The work presented contains information regarding the presence of gypsum and resulted from data collected through drilling for water, coal or oil in the St. Louis limestone formation.

Strippable Coal Reserves Of Illinois, by William H. Smith, Circular 228, *Illinois State Geological Survey*, Urbana, Ill., 39 pp., 1957—The first of a series of reports undertaken by the Illinois State Geological Survey to summerize present knowledge of strippable coal reserves in the state, and delimit areas favorable for further exploration. Much of the information is embodied on maps that show the outcrops of the coal beds, coal thicknesses, and categories of overburden by thickness.

Monograph No. 1, Volume 1—Phase Relations of Gas Condensate Fluids, by the *American Gas Association*, Order Dept., 420 Lexington Ave., New York 17, N. Y., $10.00, 1957—A report describing tests that can be used to determine the properties of gas and natural gas liquids at various temperatures and pressures. Apparatus and techniques employed are described in detail and many useful tables, drawings, photographs, and illustrations are included.

A Mineral Map of Ontario, is now available from the Publications Dept., *Ontario Dept. of Mines*, Ottawa Ont. $1.00, 1957—The map, believed to be the largest one of the entire Province ever to be printed on a single sheet, shows the basic geology of the Province and the location of the principal mines and mineral occurrences. The map is printed in eight colors, measures 50 x 50 in. and has a scale of 1. in. to 20 miles.

The Geological Section of the Proceedings of the Academy of Sciences, USSR, (Doklady) English translation, is now available from *Consultants Bureau*, 227 W. 17th St., New York 11, N. Y., at a subscription rate of $200.00 per year for the six issues. The Geological Section presents a comprehensive survey of the most advanced Russian research in geology, including reports on geophysics, hydrogeology, petrography; etc. Tables of contents will be mailed free on request.

•ORDER BOOKS SO MARKED THROUGH AIME—
Address Irene K. Sharp, Book Dept. Ten percent discount given whenever possible.

Centrifugal and Axial Flow Pumps, by A. J. Stepanoff, *John Wiley &*

(Continued on page 1202)


WELCOME THE MAN
WITH THE RED VALISE

Books

(Continued from page 1199)

Sons, 2nd edition, 462 pp., $12.00, 1957—Revised and expanded to include the considerable progress in the theoretical reasoning, design, and application of centrifugal pumps, which has appeared since the publication of the first edition. The author includes a number of new topics dealing with theory, design, and application. •

Geology and Petrography of the Stendel Perlite Deposit, Socorro County, N. M. Circular 44, by Robert H. Weber, *State Bureau of Mine & Mineral Resources*, Campus Station, Socorro, N. M., 22 pp., 10¢, 1957—This report summarizes the preliminary results of one segment of a continuing field and laboratory study of perlite deposits by the state Bureau of Mines and Mineral Resources.

High-Purity Dolomite Deposits of South Central New Mexico, Circular 47, by Frank E. Kottlowski, *State Bureau of Mines & Mineral Resources*, Campus Station, Socorro, N. M., 43 pp., 50¢, 1957—This report is designed to bring to the attention of producers and consumers of magnesium and magnesium compounds the large reserves within New Mexico. It gives quantitative and qualitative estimates of the high-purity dolomite deposits, and is especially concerned with the south-central part of the State.

Industrial Water and Industrial Waste Water, *American Society For Testing Materials*, Special Technical Publication No. 207, 52 pp., $2.00, 1957—This book is of interest to chemists, water and sanitary engineers, and all those concerned with the source, processing, use and disposal of industrial water. The material presented herein covers several aspects of this increasingly important problem. •

Behavior of Materials in the Earth's Crust, Papers and Discussion from the Second Annual Symposium on Rock Mechanics, the Quarterly, *Colorado School of Mines*, Golden, Colo., Vol. 52, 3306 pp., $2.00, 1957.—This volume covers the aspects and problems of rock engineering in the mineral industries today, along with questions and answers from the discussions on geology, behavior of materials, instrumentation, and support of workings, etc.

Halite Deposits in North Dakota, Report of Investigation No. 28, by S. B. Anderson and D. E. Hansen, *North Dakota Geological Survey*, 3 maps, free, 1957—This work outlines and defines the salts occuring in the Devonian, Mississipian, Permian, and Triassic Systems in North Dakota and its utilization. Included with the data are two thickness maps of eleven separate mappable deposits of salt and a full collor pre mesozoic paleogeological map of the state.

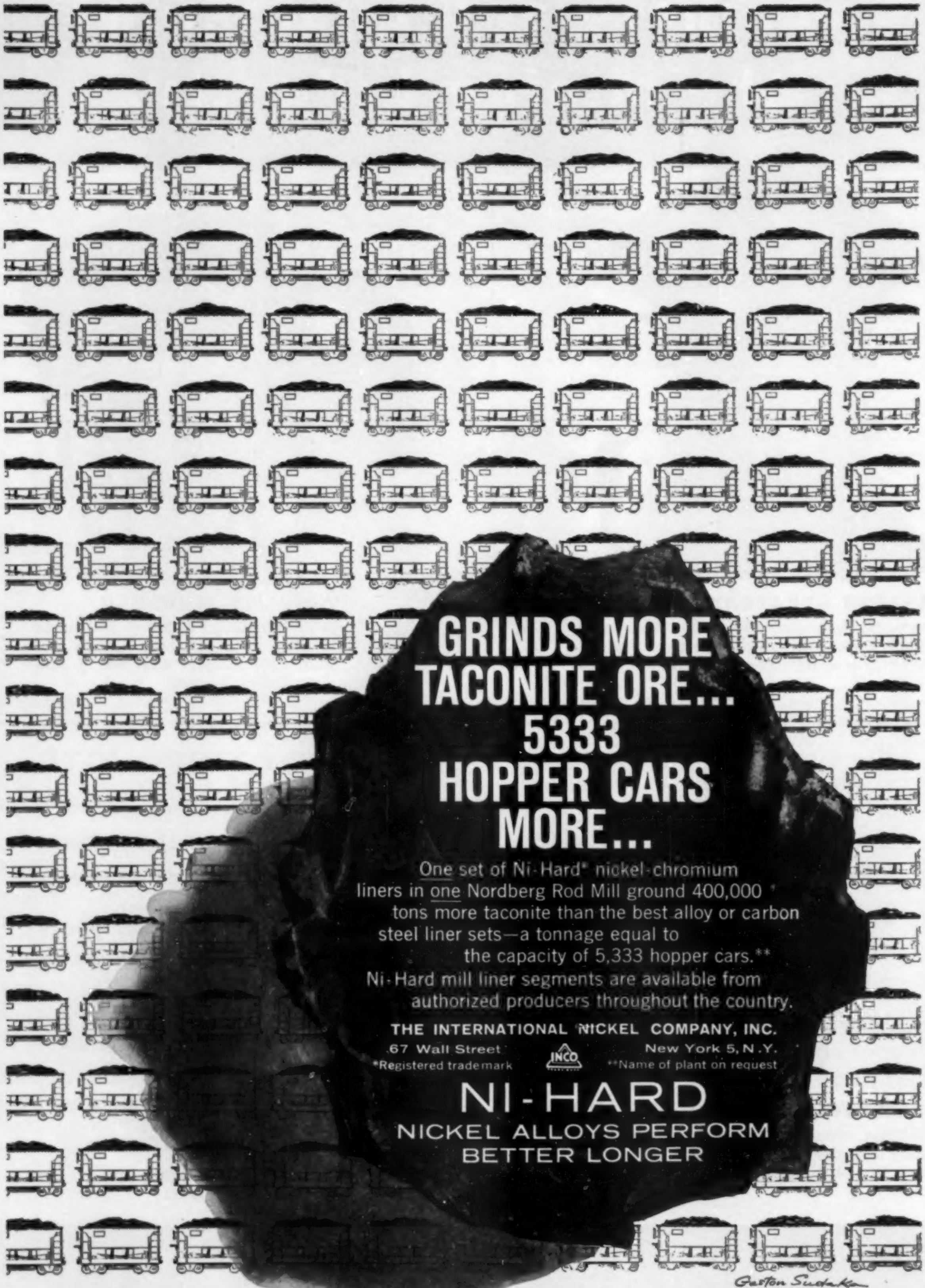
American Geophysical Union: Transactions, Vol. 1-12, 1920-1931, *Johnson Reprint Corp.*, 111 Fifth Ave., New York 3, N. Y.—The initial run of the Transactions has long been out of print but will now be available again in bound form, in December 1957. Paper bound set (of nine volumes) $80.00. Volumes 3 and 5 were never published. Other prices for single volumes are available if desired. Volumes 13 to 34, 1932 to 1953, will also be reproduced as soon as there is sufficient demand to warrant the undertaking of a reprint edition. •

Positions Open

(Continued from page 1182)

perience in handling labor required. Knowledge of Spanish essential. Location, Mexico. F5074.

Mine and Mill Superintendent, with experience in vein mining, both underground and surface, mapping and general layout; also good experience on magnetic separation, air tables screening for a magnetite uranium operation. Salary, $10,000 to $12,000 a year. Location, East. W4999.


GRINDS MORE TACONITE ORE... 5333 HOPPER CARS MORE...
One set of Ni-Hard* nickel-chromium liners in one Nordberg Rod Mill ground 400,000 tons more taconite than the best alloy or carbon steel liner sets—a tonnage equal to the capacity of 5,333 hopper cars.**
Ni-Hard mill liner segments are available from authorized producers throughout the country.
THE INTERNATIONAL NICKEL COMPANY, INC.
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*Registered trademark
INCO
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NI-HARD
NICKEL ALLOYS PERFORM BETTER LONGER
Gaston Sudaka

Iron Ore Firms to Merge

Oglebay, Norton & Co. directors proposed merging ten companies in shipping, mining and related fields with the surviving corporation to be called the Oglebay Norton Co. Included in the plan are Montreal Mining Co., Columbia Transportation Co., Ferro Engineering Co. Pringle Barge Line Co., Saginaw Dock & Terminal Co. Richwood Sewell Coal Co. Fairport Machine Shop Inc., Northshore Land Co., and Standard Box Co. Merged firm would have assets in excess of $50 million and would continue the 103-year old Oglebay Norton name.

Nickel Developments

Nicaro nickel plant was in the news again as GSA announced plans to sell or lease the $100 million plant, second largest nickel producer in the Free World (50 million lb nickel per year). . .Largest industrial order for fabricated titanium in the history of the industry will put 7 miles of seamless titanium pressure tubing in Freeport Sulphur's upcoming Moa Bay plant in Cuba.

Copper Picture Still Topsy-Turvy

September was marked by a succession of headlines reporting further copper price cuts here and abroad, together with production cuts; then copper strengthened on the New York Stock Market, reflecting marked improvement in August deliveries. Announcing it would not try to dispose of surplus copper stocks for some time, the British Board of Trade referred to the "disturbed state of the copper market." . . .Sulphur, too, got into the act as slightly nervous producers cut prices about $3.00 per ton citing "general competitive conditions." One worry lay in increasing output from the Mexican properties.

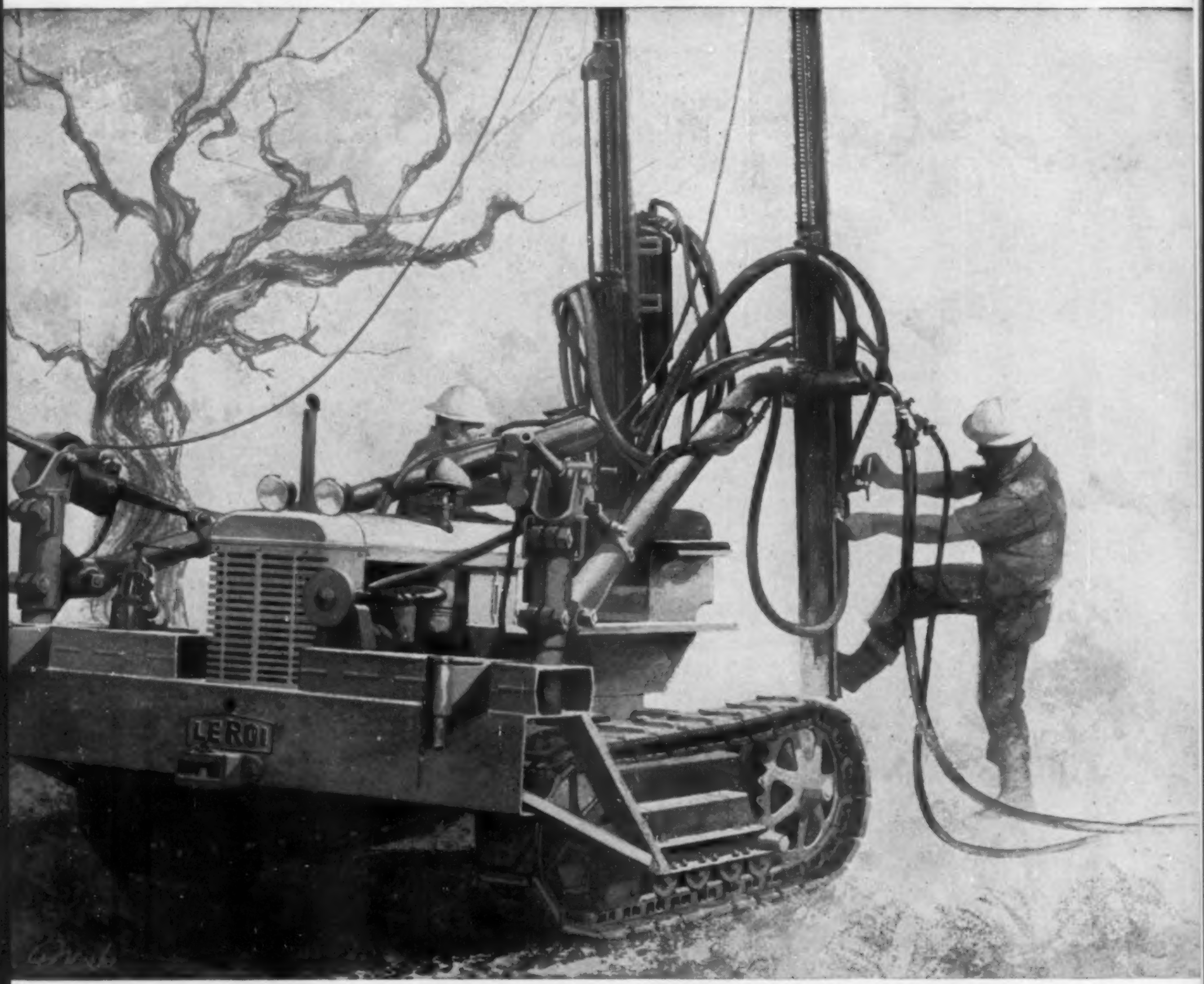
Iron Ore from Ungava Finds Market

If Alfred Krupp, German steel magnate, and Cyrus S. Eaton, Cleveland industrialist, go through with present reported deal, Eaton's Ungava Iron Ore Co. will have financing and a market for its $200 million development in the far north. One problem—Ungava Bay is free of ice but four months a year—will be met with a fleet of 70,000-ton vessels. Operations would be only 500 miles south of the Arctic Circle.

Two Uranium Mills Open

Moab, Utah, celebrated dedication of the $9 million mill of Uranium Reduction Co., marking completion of Charlie Steen's favorite project. The plant is operated by American Lead, Zinc & Smelting Co. First units went into operation in 1956, and according to AEC, the mill already ranked as the second largest U. S. producer. . .AEC reports Philips Petroleum Co. is also getting into the act as the fourth uranium milling contract was signed for production from Ambrosia Lake ores. Philips will build the 1700-ton mill in McKinley Country, N. M. . . . Not going ahead, however, is the proposed Ohio Oil Co. project to extract uranium from lignite in the Dakotas. Project was shelved, "pending development of improved ore processing or a greatly increased demand for uranium oxide.". . .In Canada, Consolidated Denison held its formal opening, although already handling 4000 tpd of ore. Within 60 days, production rate will be 6000 tpd.

LeRoi Dual Drill Rigs



Check these comparative features!

mobility:

1. The T-286 can quickly speed across job-sites without compressor power.

The air-driven track-type wagon drill can't move without an air compressor — must be loaded and unloaded by a crane.

2. The T-286 unit can travel 7 mph — and pull the compressor, too!

The air-driven unit can only travel 3 mph.

3. The T-286 has three forward speeds for better control, faster movement.

The air-driven unit has but one forward speed.

cost:

4. The T-286 costs 20% more than an air-driven track-type wagon drill, BUT you get two drills instead of one—twice the production!

5. The T-286 tractor unit alone costs slightly more than the track-type drill carrier, but it has extra usefulness—does other tractor work when not drilling.

T-286 unit features more power and speed for quicker positioning than track-type wagon drills.

Out-perform All Others!

Air motors do all the drill positioning, relieve most of the manual work

The Le Roi T-286 is a dual-drill rig mounted on a 28 hp crawler tractor. It gives you twice the production of competitive single-drill self-propelled units — yet costs only slightly more.

Its power and speed exceed that of other crawler wagon drills, giving faster movement across job-sites . . . quicker positioning . . . higher production.

Besides being a major time-saver, the tractor is useful after rock-work is completed; drills can be easily removed to permit use in cleanup work and other odd jobs. Yet the tractor itself costs only slightly more than a slow-speed air-driven self-propelled drill carrier!

Goes Anywhere

The T-286 is ideal for work-sites that are inaccessible to standard-type drill rigs. It can easily travel to places where manual positioning of wagon drills is slow and impractical — quickly reaches spots formerly drilled only with even slower and doubly back-breaking hand-held rock drills!

The crawler tractor takes rough ground easily. A parking brake and two leveling jacks stabilize the tractor while drilling on rough or uneven ground.

In operation, air motors position the drill arms through a wide arc, permitting easy, quick setups for any number of holes without relocating the machine. Each arm has a 7 ft. radius through 220 degrees . . . distance between drills is a maximum of 24 feet, allowing a variable drill pattern.

Drills High or Low Holes

Air motors change the positioning of the air feeds, too, through 360 degrees. This means easy placement of horizontal flat holes as high as 9 feet above ground level, as well as toe holes either backward or forward. Feed is positive whether the drill is being fed forward or retracting, giving faster drilling with both steel and tungsten carbide tipped bits.

The heavy-duty feed allows the use of either 3½ in. or 4 in. drifter with 10 ft. travel and 8 ft. steel change as standard equipment. Other size steel changes are available.

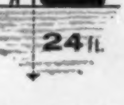
The dual drill rig may be bought separately for installation on *any* make tractor you now own. Write today for complete information on this useful high-production tool.

LE ROI DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY, MILWAUKEE 1, WISCONSIN

MANUFACTURERS OF CLEVELAND AIR TOOLS, TRACTAIR®, PORTABLE AND STATIONARY AIR COMPRESSORS, AND HEAVY-DUTY INDUSTRIAL ENGINES. WRITE US FOR INFORMATION ON ANY OF THESE PRODUCTS.

production:

6.



With its double drills, the T-286 can put down twice the footage of any air-driven wagon drill; handles holes up to 2¾ inch and depths to 24 ft.

7. 30

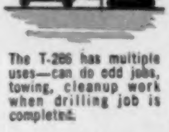
The T-286 can put in many holes—10, 20 or 30 — from one tractor setting. Wasteful moving and set-up time is eliminated.

1

The air-driven wagon drill puts down one hole per setting — must be repositioned for each hole.

utility:

8.

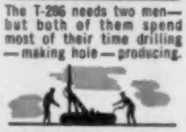


The T-286 has multiple uses—can do odd jobs, towing, cleanup work when drilling job is completed.

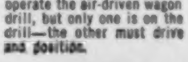
The air-driven wagon drill has only one use — is a dead investment when not drilling.

manpower:

9.



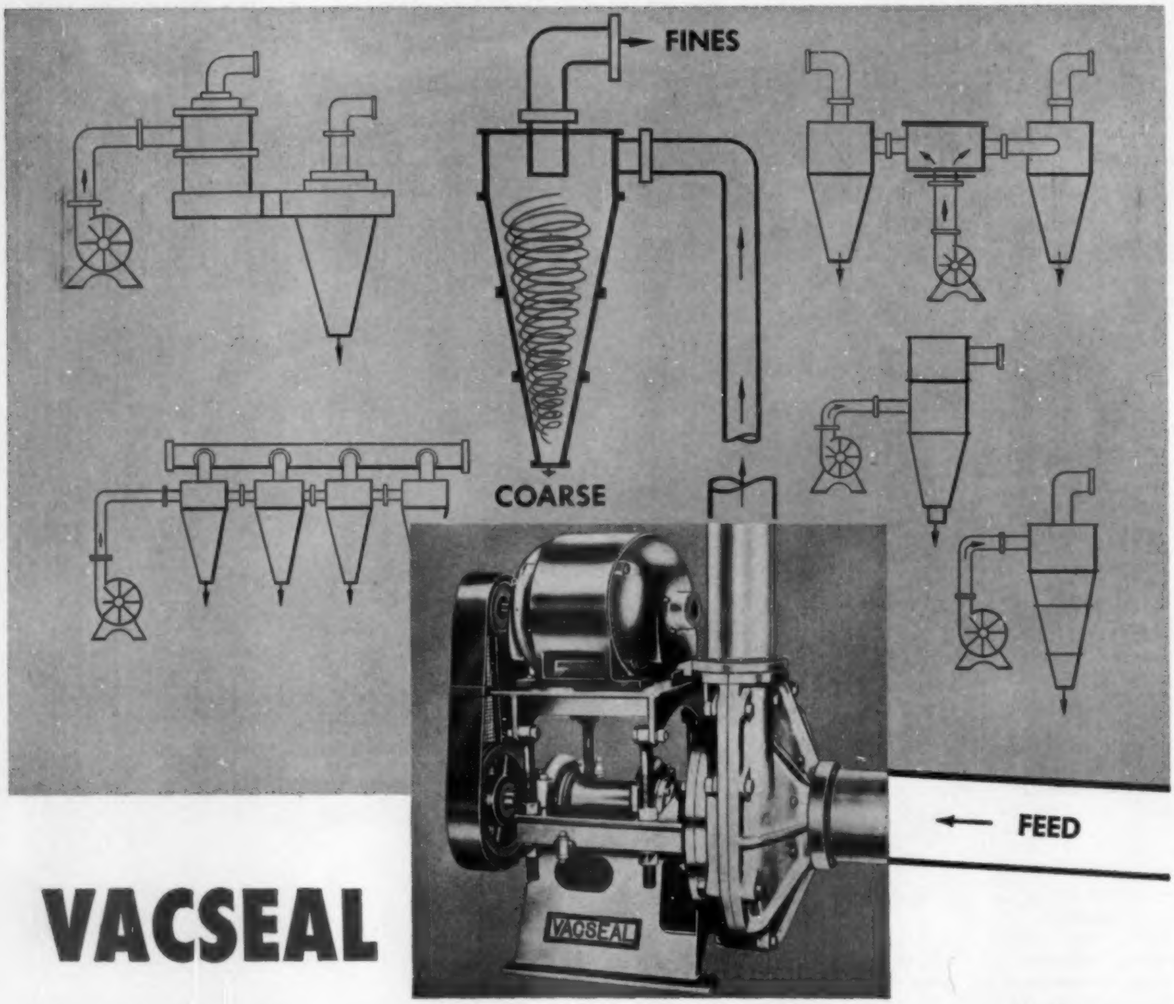
The T-286 needs two men—but both of them spend most of their time drilling —making hole—producing.



It also takes two men to operate the air-driven wagon drill, but only one is on the drill—the other must drive and position.

How about it?

Can you afford to tie your money up in a low-production, one-use tool—when for slightly more you can get double production plus high quality?


FINES
COARSE
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South Africa as a Leading Uranium Producer

Easing of security restrictions permits accurate appraisal of uranium reserves in the Rand.

South Africa's uranium ore potential of 1.1 billion tons is now revealed as the world's most extensive uranium deposit, exceeding all known reserves on the North American continent. On the strength of present figures the U. S. and Canada can produce uranium for about 10 years, South Africa for 60 years. Developed with American and British capital, South African deposits now provide 20 pct of the Free World's supply.

In 1956 the industry's total output of uranium oxide was 4400 tons, as compared with U. S. production of 6000 tons for the same year. It is expected that during 1957 South African production will increase to more than 5000 tons and U. S. output to more than 8000 tons. Canadian output, estimated at 4750 tons for 1957, is expected to rise sharply to 14,000 or 15,000 tons by mid-1958.

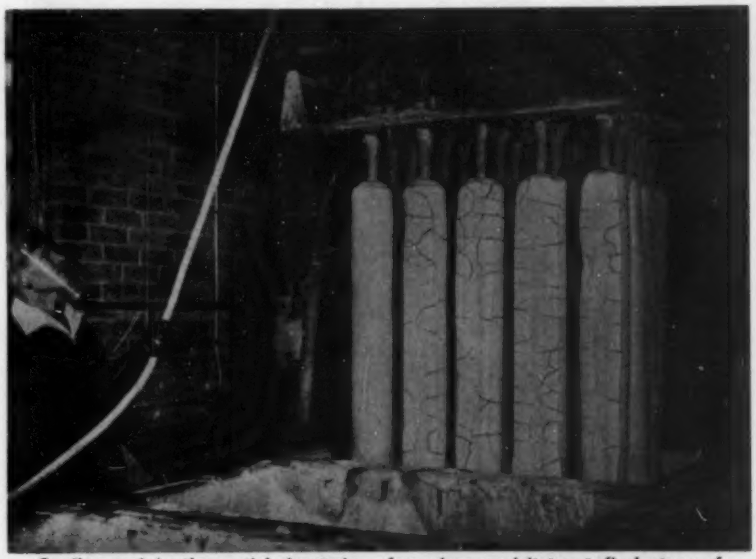
Originally a byproduct of the gold mines, the uranium extracted from South Africa's gold-bearing ores often produces a bigger profit than the gold itself. Pyrite is also recovered from the ore reefs for production of sulfuric acid, which in turn is used to extract the uranium.

Extreme Low Grade

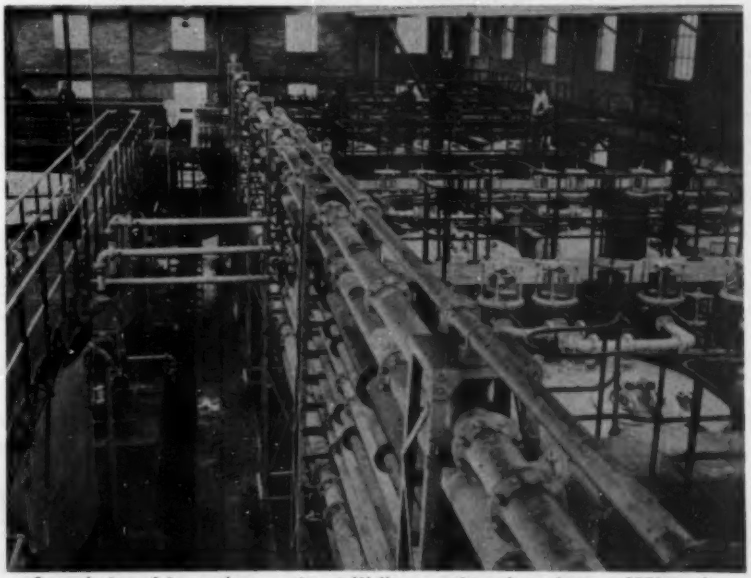
Uranium occurs in most of the gold reefs as a mixture of hydrocarbons and uraninite. Although the deposits are extensive, the uranium oxide content is low, averaging 0.470 lb per ton of ore treated in 1956. With few exceptions, it would not have been possible to operate the mines for production of uranium alone, but the disadvantage of low grade has been largely offset by the fact that the uranium is mined simultaneously with gold. Cost of production is limited, therefore, to the cost of recovery from slimes produced in the gold recovery plants. The orebodies are regular and consistent, so that reserves can be assessed with the same accuracy possible in calculating the reserves of gold.

Wet precipitate is sent to a central calcining plant operated by Calcined Products (Proprietary) Ltd. Undertaken as a wartime proj-

(Continued on page 1213)



Candles used in the partial dewatering of uranium precipitate at final stage of extraction process.



General view of ion exchange units at Welkom uranium plant. Average 1956 grade of uranium oxide was 0.470 lb per ton of ore treated. Highest grade recorded for a single mine last year was 1.392 lb per ton at the West Rand Consolidated mine, which produced 1,244,724 lb of uranium oxide.

AIME Annual Meeting

New York

February 16—20, 1958

- Technical Program
- Social Events
- Post-Convention Triangle Cruise

See MINING ENGINEERING, November 1957, for more detailed program information.

South African Uranium

(Continued from page 1211)

Uranium taken by the Vesin sampler is taken to the sampling office. Here the product is treated further, and a number of small samples are made up for delivery to the works laboratory and to the laboratories of the country to which the material will be sent.

ect with backing of the U. S. and Britain, this $4.2 million plant was kept secret for five years until early 1957. Here the entire output of South Africa's uranium industry is processed into a granular export product averaging 85 pct uranium oxide.

Nearly Forgotten

Despite its recent prominence in the world production picture, uranium in South Africa is no new discovery. Nearly forgotten by the time the world search for uranium was under way, samples from South African gold mines were brought to the U. S. in 1914 by G. W. Bain of Amherst College, Mass. Radiometric tests of the samples in 1945 proved their uranium content.

Miners Take Fall Convention Circuit; Start With AMC Meet

Kick-off for the full round of mineral industry meetings came in Salt Lake City September 9th to 11th, scene of the 1957 American Mining Congress gathering. One major stop for the month-long, cross-country tour of the Sixth Commonwealth Mining and Metallurgical Congress came September 27th and 28th at Toronto. Delegates to the Congress traveled 3700 miles across Canada, visited 50 mines as well as smelters, steel mills, etc., and took back to their 45 countries a picture of the sources of Canada's $2 billion dollar annual mineral output.

In the following weeks, mineral industry engineers and executives will be converging on Tampa, Fla.; Quebec; and Denver to take part in three AIME-sponsored meetings: The First Annual Meeting of the Society of Mining Engineers of AIME, the Annual Joint Solid Fuels Conference, and the Third Annual Rocky Mountain Minerals Conference.

The Mining Congress in Salt Lake City drew an estimated 3300 delegates, including a host of representatives, senators, and other political figures. Those attending the convention had plenty to talk about as the season permitted full evaluation of the fast-moving developments that had occurred in the nonferrous metals field during the summer months. One New York paper reporting on the meeting in Salt Lake City headlined "Gloom Darkens Mineral Parley." Below this the story highlighted price slump and shut-downs as dominant issues at Salt Lake.

First-hand impressions out there did not equate to "gloom" but serious discussion and some worry were certainly in the air. Government mineral policies, particularly mining rights on the public domain, labor relations, and problems of tariff or sliding scale import duties came in for heavy discussion. Perhaps appropriately, the final-day session was devoted to a tax and accounting discussion.

For more complete summary of the 1957 AMC statement of policy, please turn to *Trends* page 1218.

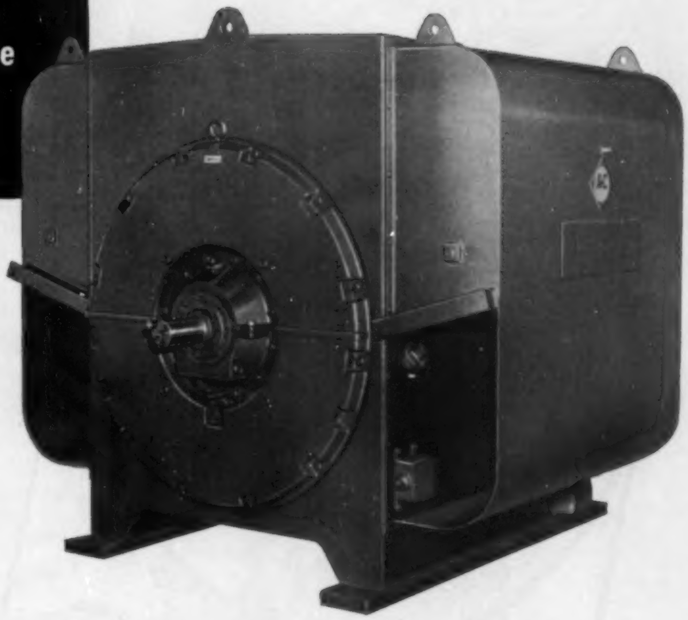
National Clay Meeting Held in California

The Sixth National Clay Conference was held at the University of California, Berkeley, on August 19 to 23. One of the highlights of the conference was the visit to Ione on August 21 for a tour of the Owens-Illinois Glass sand-beneficiation plant and the Gladding, McBean & Co. clay washing plant, both of which were constructed in 1955.

Those attending the conference visited Owens-Illinois' clay-sand pit, the sand processing plant, and the clay-washing plant which treats the material derived from the pit. At the Gladding, McBean operation, the plant trip visitors had a chance to examine the laterite pit at Jones Butte, the adjacent McGuire fire clay pit, the stratigraphic column exposed at Gage Hill, and the Indian Hill refractories specialties plant. Those geologists and mineralogists in the group were able to examine the depth of alteration of the diabase to form laterite at the laterite pit and the kaolinization of a conglomerate lying between sedimentary clays and base shales at the Gage Pit.

George Cleveland, California State Div. of Mines, was chairman of the field trip committee for the Conference. Luncheon for the occasion was provided by Owens-Illinois Glass Co. and Gladding, McBean & Co.

"Modern Copper Concentrator at Silver Bell, Ariz., for American Smelting & Refining Company"



International Nickel Grants for Education

International Nickel Co. Inc. has renewed its scholarship at the Colorado School of Mines and has made a contribution to the school's development program.

The scholarship, established last year, pays all tuition and fees, and provides the recipient with $300 annually for his four years at the school. Winner of the scholarship for the current year is Frederick Schwarz, a mining geology student from Mountain Lakes, N. J.

Concerned with minerals as it is, Inco requested that the scholarships be restricted to students who are working in an option dealing with ores. Otherwise, no limitations were placed on the scholarship.

Inco's contribution, made in addition to the scholarship, is an unrestricted gift to the Colorado School of Mines Foundation Inc. Dr. John W. Vanderwilt, president of the School, said that the money would be used immediately in the faculty development phase of the Horizon Plan, the school's development program.

International Nickel has also endowed Columbia University with $350,000 to establish a Chair in Chemical Metallurgy. The company has made an additional gift of $75,000 to the University for special expenditures incidental to establishment of the Chair.

50 Books Received By Colorado Mines School

Frontier Refining Co. has contributed 50 books to the Colorado School of Mines Library as a memorial to the late Harold D. Roberts. Mr. Roberts, who was awarded an honorary doctor of engineering degree from the school in 1946, was legal consultant to Frontier Refining. He was a member of the firm of Holme, Roberts, More, Owen and Keegan, attorneys.

The gift to the library was presented by M. H. Robineau, Frontier president, in the form of a check for $500 to the Colorado School of Mines Foundation Inc., with the request that the gift be used through the school's development program to provide memorial books for the library.

Colorado School of Mines used the money to buy technical books dealing with various phases of the petroleum industry, in compliance with Frontier's request. A special book plate, identifying it as the Harold D. Roberts book, has been placed in each of the 50 volumes. The collection is now being used by students at the Colorado School of Mines.

THE formal declaration of policy by the American Mining Congress, adopted at Salt Lake City, covered seventeen topics, every one of which related to the Federal Government with the exception of that headed Water and Air Pollution and there, too, the principal discussion was of the Government's role. Some of the points made were as follows:

► *Government Expenditures*—a plea for a limitation of Government expenditures to the essentials. Aiming for tax relief in 1958 consistent with a balanced budget.

► *Taxation*—emphasis that the tax system must be such as to yield needed revenues without discouraging investment. It was noted that the present internal revenue code incorporates desirable improvements but further revision is needed. AMC stresses that it is essential that depletion depreciation and net loss carryover be fully and adequately allowed and be not less than authorized by the present code. Nine specific points are cited dealing with present tax rates, expenditure allowances for exploration, provision for new mines for capital gains adjustment and for new regulations affecting corporations involved in foreign operation.

► *Labor Relations*—the resolution commends the McClellan Committee for its services in revealing unchecked power of labor leaders. Purged are Congressional Acts to eliminate devices which might emphasize Union monopoly in certain fields, this to provide greater democracy and protection for rank and file Union members from those Union leaders who are unscrupulous.

► *Need for National Mineral Policy*—stressing the need for consistent programs they point out that the industry stands ready to aid in the formulation of a sound policy.

► *Tariffs*—five points made here include: (1) Import taxes established to protect those metals and minerals substantially produced domestically, and to take effect at a set price only. (2) Those metals and minerals in scarce domestic supply to be provided special Government assistance to encourage their continuance as industries. (3) Recommendation that import quotas be provided in certain cases when no other device is feasible. (4) Request for amendment of the Anti-Dumping Act of 1921 to give greater certainty, speed and efficiency in administration and enforcement.

► *Stockpiling*—stresses that no withdrawals should be made in the stockpile except in a declared emergency for purposes of National security and stresses that Government commitments for purchases should be fulfilled and that Congress should appropriate the required funds therefor.

► *International and United Nations Commodity Agreements*—voices strong opposition to inter-Governmental efforts to control price and production.

► *Solid Fuels*—urges the five-point solid fuels policy concerning natural gas pipeline companies, crude oil production, additional research for uses of coal, increased depletion allowance for solid fuels, and opposes amending the Mineral Leasing Act of 1920.

► *Public Lands*—urges certain amendments to the general mining laws to afford protection to those engaged in exploration prior to discovery of mineral. Also opposed to the creation or continuance of withdrawals of land of mining location except in cases where the National interest clearly justifies such action.

► *Mine Safety*—under seven points, the policy declaration stresses continuation and strengthening of the present industry safety programs and continued cooperation of the Bureau of Mines and Public Health Service.

► *Water and Air Pollution*—urges that the solution of pollution problems is both the responsibility and right of local and State jurisdictions.

► *Gold, Silver, and Monetary Policy*—As in prior years, the AMC position repeats a recommendation for the return to relatively free gold and silver transactions in order to "provide a program that would be beneficial to the entire country as well as to the industry with which we are primarily concerned."

► *Uranium*—encourages the AEC efforts to develop private industry activity in research and development of the nuclear reactor program.

► *USGS—USBM—BLM*—in general commends the activity of these agencies, requests accelerated mapping, urges better financing, and urges transfer of all Federal responsibility affecting mineral sources to the Department of the Interior.

► *Government Reorganization*—endorses the work of the two Hoover Commissions and urges early and favorable action on further Hoover Commission proposals.

► *Mine Financing*—commends the constructive position taken by the SEC during the past year and recommends a program at least as favorable as the EMEA plan, one with adequate funds provided by Congress.

► *Radio Frequency Allocations*—requests the modification of rules for industrial radio services published by the FCC, in order to eliminate discriminatory treatment of mining.

NEWS from the titanium front has been mixed, as has been pricing, production, and marketing news for all nonferrous metals in recent months. Cutbacks of military expenditures, especially in the Air Force program, bode no good for titanium producers, but despite this, MINING ENGINEERING *Reporter* last month outlined plans for the formation of the largest integrated titanium producer, Mallory-Sharon Metals Corp. This new firm will have a complete

range of research, development, sponge production, and metal fabrication facilities.

Formation of the new firm may represent a belt-tightening procedure, faith in continued industry growth, or simply more convenience. A more useful straw in the wind lies in a story reported this month in MINING ENGINEERING *Reporter*—Titanium Metals Corp. of America's announcing agreement to supply 7 miles of titanium piping to Freeport Sulphur for its Moa Bay nickel operation. Apparently the answer to the Air Force cut-backs lies in acceleration of non-military application, and here one of the greatest immediate possibilities is the chemical industry. As for the mining industry, titanium applications might be looked upon as one metal helping another, as piping, valves, and special fixtures of titanium provide answers to hitherto costly or impossible-to-solve problems in the chemical recovery and refining of metals. A visit to a cobalt plant underlined the vital role played by titanium, one of the jet-age metals, in making economic the production of another metal making headlines in the turbine and jet field.

Titanium producers are now in a particularly good position to go after civilian markets, since potential consumers need have no fears as to the companies' abilities to supply. In effect, Air Force cutbacks will probably leave the industry running at about 40 pct of capacity. And this production capacity will be upped by the new Kennecott Copper Corp.—Allied Chemical & Dye Corp. titanium plants scheduled for late 1958 production. In fact, by the end of 1958, titanium production should well exceed 40,000 tons per year.

Likely to be trimmed in a competitive market, providing that demand permits mills to operate at a reasonably economic capacity, are current prices for sponge and mill products. Already down from the $5.00 per lb 1954 level to the present $2.25 per lb, further reductions in sponge price will come harder unless there is adequate production volume. Volume is one answer, technology another answer to the problem of how to reduce composite mill product price, now averaging about $10.50. It boils down to this: on a per pound basis, titanium is not cheap, but for many difficult applications it is already the least expensive answer. Some of these places are high pressure pumps handling acids, valves, piping, heat exchangers, pressure units, and the like in chemical plants and metal refining plants. In short, if they come up with a near-perfect solvent in future years, it is likely that titanium will provide the near-perfect vessel to keep it in.

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IN the midst of waiting for more depressing news, two items of a lighter vein passed across the desk in the past month. A feature story out of Uranium City, Saskatchewan, in connection with the official opening of Lake Cinch Mines Ltd., notes that operations there are being run by the first woman to enter the uranium field in Canada, Mrs. Viola MacMillan. Already a successful prospector and president of five mining companies, she has caused old-timers to feel "well, now they'd seen everything." Incidentally, *Mr.* MacMillan has his own mining interests and serves as director in some of the companies his wife heads.

Under the "not leaving a stone unturned" philosophy, the Denver City Water Board has granted Climax Molybdenum Co. the right to examine the Board's latest tunnel excavation for mineral possibilities. The Board says "we are in the water business, not the mining business, but if we run across some ore, it means potential additional revenue for Denver taxpayers." Examination by Climax will cover the $42-million dollar, 23-mile Roberts Tunnel passing deep beneath the Continental Divide, eastward from Dillon, Colo. The Board manager noted that they don't know what they will run into inside that mountain—but it's obvious that they are not going to take a chance that they'll miss it if it is mineral. After all, it isn't every day that you can get someone else to pay for a 23-mile tunnel in the Colorado mountains.

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GREATER nickel production and research "should serve to reassure even the most skeptical consumers that there can be a gradual restoration of established uses for nickel, and that nickel can safely be considered for long-range plans." Tracing the turns of nickel and the nickel industry recently, C. M. Schwitter, market research manager of International Nickel Co., stressed that up to the present time a heavy percentage of the Free World nickel supply was absorbed by defense and U. S. stockpiling requirements. He pointed to Inco's efforts in increasing the civilian nickel supply by expanding underground operations and noted the upstep in ore tonnage produced by his company—from 6 million tons per yr in 1946 to 14 million today.

It is the aim of Inco to increase its production by 100 million lb by 1961. Free World capacity at that time would then be at a yearly rate of 650 to 675 million lb, meaning considerably more than twice as much nickel for civilian consumption than was available in 1956.

With regard to technical development and research at Inco, Mr. Schwitter said: "In 1955 Inco spent 1.7¢ per net sales dollar on technical development and research. The entire primary metals industry in the U. S. spent less than one-third of this amount during the same period." He maintained that it was this kind of strong technological effort that pulled the industry out of its 1920 doldrums, made major contributions to the field of aviation, and is furthering the work of the guided missile and atomic energy programs.

Part of the Inco development program—expenditure of some $175 million in putting the Mystery-Moak Lake area into production—will be detailed in a future issue.

Caterpillar announces in the world's most

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Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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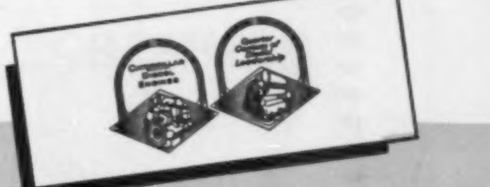

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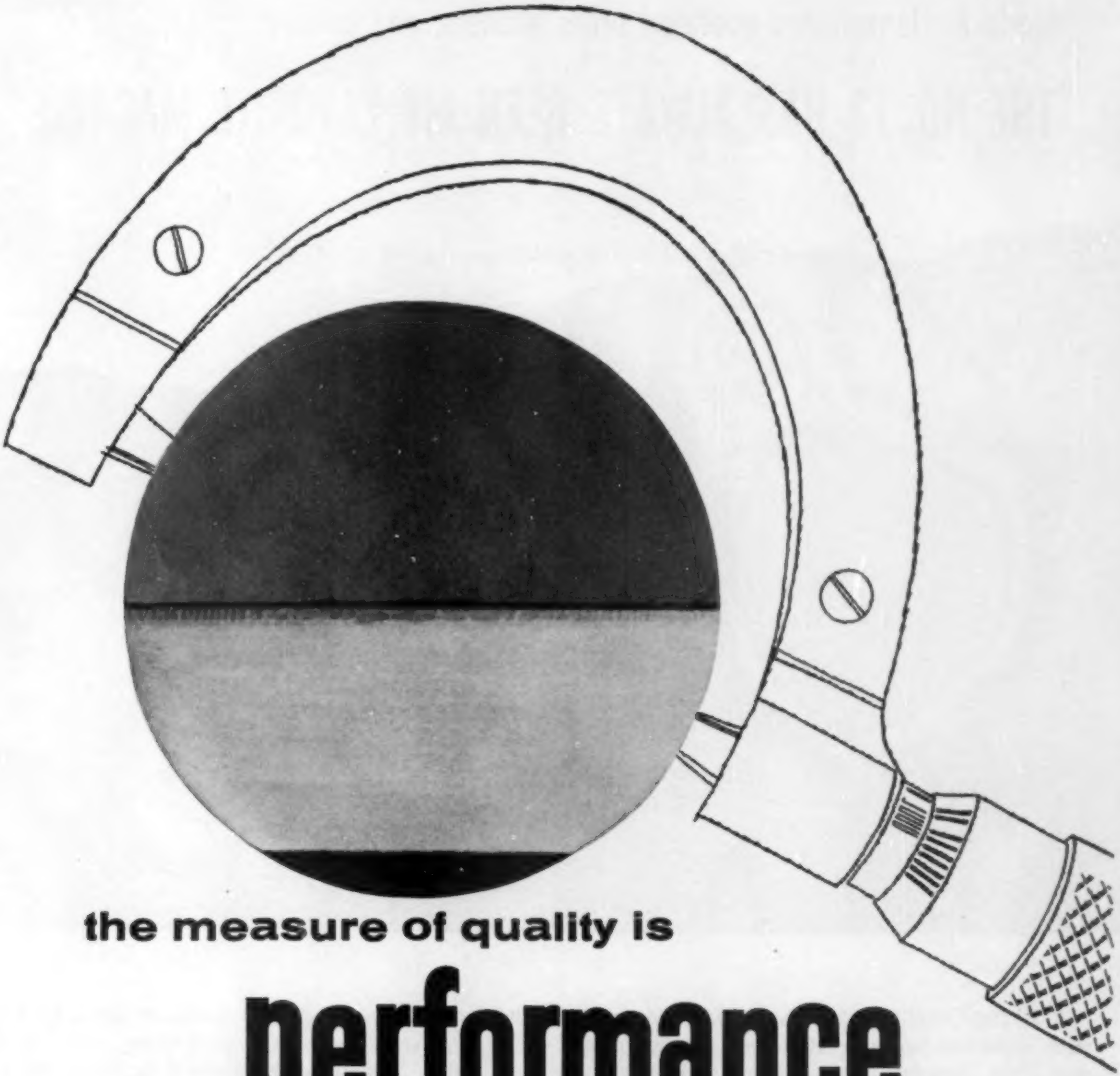

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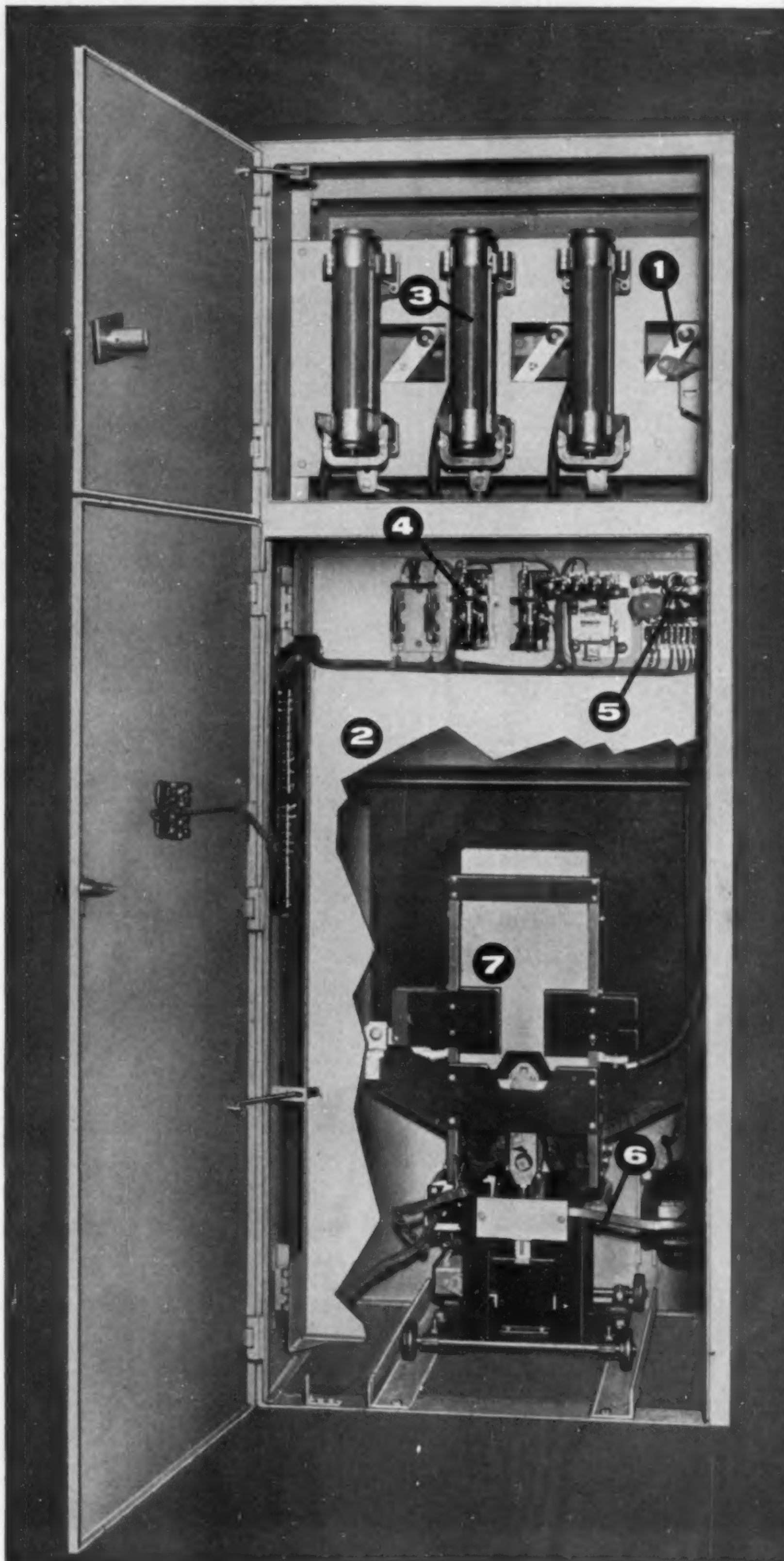


Milling Practice at the Lavender Pit Concentrator

by H. K. Martin

IN September 1954 the Lavender pit concentrator at Lowell, Ariz., began treating low grade porphyry copper ore from the nearby Lavender mine. Nominal capacity of the mill is 12,000 tpd, but production now averages 16,226 tpd.

Plant design was somewhat affected by the re-use of old equipment and the substantial re-use of old buildings. A breaking-in period between June 24 and Sept. 1, 1954, was devoted to training operators and making minor changes in launders, chutes, and piping. From Sept. 1, 1954, to July 1, 1956, the mill treated 8,598,105 dry tons of ore, from which 556,541 tons of concentrate were produced, containing an indicated 144,055,185 lb of copper.

Ore: The ore is a completely altered igneous rock. Original composition probably bordered between a rhyolite and quartz monzonite porphyry. Hydrothermal alterations have replaced some of the earlier minerals with finely disseminated pyrite. Original copper content was probably very low, but sulfide enrichment has coated and replaced the pyrite to some extent with chalcocite. The chalcocite occurs as rims around pyrite grains and as minute veinlets along innumerable fractures within the pyrite grains, many of which have a network of chalcocite veinlets. There is no evidence of complete replacement of any pyrite grains by chalcocite. Microscopic examinations of polished sections show a great many of the chalcocite veinlets to be 1/100 mm thick and less. The microscope has not revealed any chalcocite other than that which is closely associated with pyrite. In 1955 the oxide copper in the ore averaged 5.2 pct of the total copper, the monthly high and low being 6.6 and 3.9 pct respectively. Most of the oxide copper is in the form of a very thin skin on the chalcocite and is barely perceptible under the microscope. Oxidation takes place rapidly after the ore is broken, particularly when it is hot and humid. There is practically no oxidation during crushing, but oxidation is undoubtedly increased by the higher temperatures occurring in wet grinding.

H. K. MARTIN is Superintendent of Concentration, Copper Queen Div., Phelps Dodge Corp., Bisbee, Ariz.

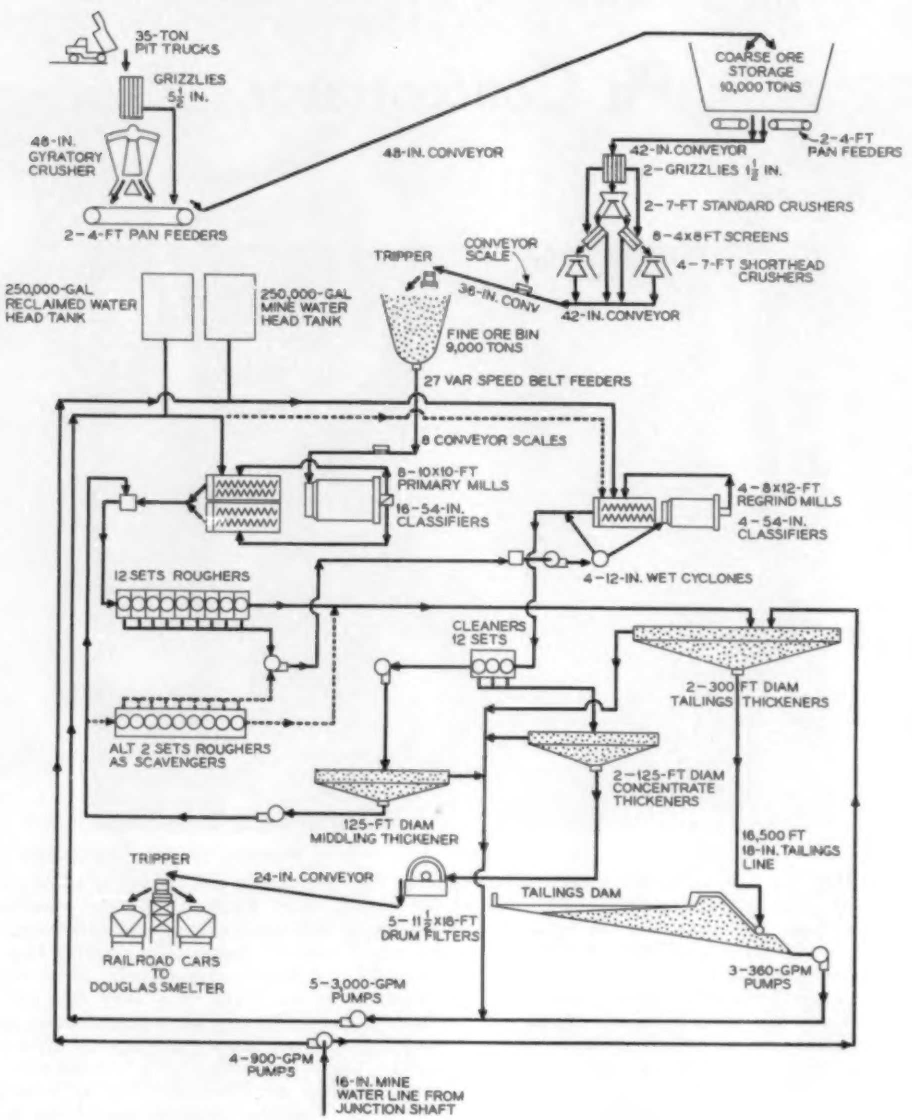
The chalcocite content in the mill heads varies greatly from hour to hour, shift to shift, and day to day. In one month the daily chalcocite content ranged from 0.86 to 1.87 pct. Hourly variations from 0.70 to 1.50 pct Cu are not uncommon.

Analysis of the ore milled in 1955 is as follows:

Content	Percent
Total copper	1.039
Oxide copper	0.054
Sulfide copper	0.985
Silica	62.10
Alumina	12.30
Lime	0.48

Primary Crushing: The primary crusher is within the rim of the Lavender pit and the secondary crusher adjacent to the mill. Ore is delivered to the 48-in. gyratory primary crusher in truckloads averaging 35 tons and dumped on each side of the crusher over 5½-in. grizzlies. Each grizzly is 22 ft

Lavender Pit Concentrator



8 in. wide by 16 ft 9 in. long, with a 2-ft center divider to distribute the feed and protect the crusher spider. The grizzlies slope 40° and have 35 pct open area. The material passing through the openings constitutes a major part of the undersize in the run-of-mill ore and averages 30 pct of delivered ore. Choke-ups of the crusher by large rocks are relieved by a collapsible hook worked from the overhead service crane, and boulders too large for crushing are removed with cables and the crane.

The grizzly undersize, along with the crusher product, discharges onto two 48-in. manganese steel pan feeders and thence to a 48-in. inclined belt conveyor (219-ft lift) to the coarse ore bin, which holds about 3000 tons of dry or 2000 tons of damp ore. Ore from the pit averages 2.3 pct moisture but sometimes runs as high as 4.5 pct. Paddle-type screw conveyors deliver spillage from the pan feeders to the 48-in. conveyor.

One 20,000-cfm and two 5000-cfm wet dust collectors provide adequate dust protection in the primary crushing plant.

The 48-in. gyratory crusher is lubricated by a circulating gravity feed system. The 700 gal of oil in the system are filtered and maintained at 90° to 100°F. Filter cartridge life is three to four months.

With new liners, the crusher is set at 5½ in. on the open side. The first mantle was changed after 4,165,100 tons were crushed and the two lower rows of concaves after 5,483,966 tons were crushed. The second mantle was changed after 4,821,667 tons.

In 1955 the primary crushing plant averaged 931 tons per operating hour and operated 65.8 pct of the available time.

Secondary Crushing Plant: Ore is drawn from the coarse ore bin by two 48-in. manganese steel pan feeders and discharged onto a 42-in. inclined belt conveyor (130-ft lift). From this conveyor it is

transferred to a short 54-in. belt conveyor, equipped with a metal detector, and is routed to either one or both sections of secondary crushers. Actuation of the metal detector by tramp iron stops the pan feeders under the coarse ore bin and conveyors.

Each of the two secondary crushing sections consists of a 1½-in. grizzly, one 7-ft standard, two 7-ft short head cone crushers, and four 4x8-ft rod deck screens. The undersize from the grizzlies, along with the product from the standard crushers, feeds the 5/16-in. opening screens. Screen oversize is crushed in the short head crushers. This product joins the screen undersize and is conveyed to the fine ore bins, where it is distributed by a 36-in. belt conveyor equipped with a single-discharge tripper car. The crushed ore is weighed in transit by a belt scale.

In 1955 the product from the crushing plant averaged 4 pct +0.525 in., 18.5 pct −65 mesh, and 12.9 pct −200 mesh.

Feed rate to the secondary crushers is indicated in the crusher operator's station by ammeters, actuated by tachometers on the coarse ore bin pan feeders and calibrated to the belt scale. Rheostats at this station regulate the pan feeder speed.

Dust collecting equipment in the secondary crushing plant consists of one 5000-cfm and two 20,000-cfm wet collectors of the two crushing sections, one 2000-cfm wet collector at the pan feeders, one 2000-cfm wet collector at the junction of the 42-in. and 54-in. conveyors, and one 10,000-cfm wet collector at the point where the ore is transferred to the tripper belt over the fine ore bin.

The crushers are lubricated by a gravity feed system, which also serves the eight primary ball mills. About 8000 gal of No. 20 Red Engine oil are used. With eight ball mills and one crushing unit operating, the oil is circulated at 300 gpm.

Liner life, based on total feed in the secondary crushing plant, is as follows:

Liner Parts	Tons
Standard upper mantle	2,050,000
Standard lower mantle	2,050,000
Standard bowl	2,980,000
Short head mantle	1,163,000
Short head bowl	1,335,000

Weight of worn out liners averages 22 pct of the weight of new liners.

In 1955 the crushing rate per section hour was 792 tons. The crushers operated 38.7 pct of the total available section operating time.

The crushing plant operates on three shifts and the operating crew is made up of one assistant shift boss, two primary crusher operators, two secondary crusher operators, one tripper car operator, and two process laborers on each shift.

Primary Grinding: The primary grinding section begins at the fine ore bin, which is of catenary construction, and has an available capacity of 7000 to 8000 tons, depending on moisture content of the ore. There are eight 10x10-ft grate-type mills driven at 17.9 rpm by 800-hp 257-rpm synchronous motors. Each ball mill is in closed circuit, with two 54-in. duplex submerged spiral classifiers set on a slope of 4 in. per ft and running 6 rpm. Drive shaft bearings and submerged bearings on classifiers are greased at controlled intervals by a central automatic lubricating system. The ore is drawn from the bin by 27 18x24-in. belt feeders. Each feeder has a slide gate and a variable speed d-c gear motor for controlling the quantity of ball mill feed. Three of the mills are fed by four feeders each and the other five by three feeders each. Ore for each unit, drawn from the bin by two or more feeders, discharges onto an 18-in. conveyor, from which it is transferred to a weighing conveyor that delivers it to the ball mill scoop housing. The new feed and classifier sands enter the mill through a 78-in. radius double entrance scoop. The drum feeder portion of the scoop is used only for ball addition. Conveyor scales weigh the feed to the mills and, through a series of relays, regulate the speed of the feeders to deliver ore at the desired rate.

Crushing Operation

Nominal mill feed size is ½ in., and the product is held between 5 and 7 pct +65 mesh, which yields 62 to 63 pct −200 mesh material. The ball mills are operated with 78 to 83 pct solids. Classifier overflows average 22.5 pct solids. The classifier sand load is estimated between 450 and 550 pct of the weight of new feed. Hydrated lime slurry is fed into each ball mill scoop housing and controlled by the operator to keep the circuit at desired alkalinity for flotation. Periodic screen tests, dilution, and alkalinity determinations are made by the operators on the classifier overflows. Alkalinity is determined by titration for available CaO.

There is a considerable range in production from the grinding units because of the large variation in grindability of the ore from different areas in the Lavender pit. The table below shows average grinding data:

Period	Feed, Pct		Product, Pct		Tons Per Ball Mill Day
	On 0.525 In.	−200 Mesh	On 65 Mesh	−200 Mesh	
Sept. 1 to Dec. 31, 1954	11.5	11.2	6.6	61.5	1,758
1955	4.0	12.9	5.5	62.1	2,042
1956 to July 1	5.7	12.0	5.4	62.6	2,121

Chrome-moly double-wave shell liners, chrome-moly and Ni-Hard feed head liners, and chrome-moly grates are being used. The original liners wore out rapidly because of the low feed rate to the mills. The first set of shell liners averaged 273 days, feed head liners 228 days, and grates 296 days. Average operating time of the second set of shell liners was 326 days, and the feed head liners 331 days. The second set of grates is still in operation at this time. Average life of scoop lips is about 80 days.

Balls are unloaded from railroad cars by magnet into overhead bins in the grinding repair bay. From these bins the balls flow into a trailer car drawn by a tramaire locomotive and are weighed on a track scale. After weighing, the locomotive and trailer deliver the balls to the various mills, where they are discharged through a side gate on the trailer into a chute, and then back into the ball mill drum feeder.

The grinding crew is made up of one assistant shift boss and three ball mill operators on each shift. Each operator looks after four units. There are eight primary mills and four regrind mills.

The grinding section is serviced by two cranes that extend out over the repair area. A 10-ton crane is used for light repairs and unloading balls from gondolas, while a two-hook 40-ton crane is available for heavy work.

All the ball mills are relined in place. Shell liners are stripped and replaced in 18 hr and feed end liners are replaced in 7 hr. When grates are replaced it is necessary to dump the ball charge into three ball buggies. The heavy duty crane is used to hoist the buggies and dump their load of balls back into the mills through a funnel. About 32 hr are required to dump, recharge the mills, and replace the grates.

Flotation Section: Flotation is divided into two sections, each receiving feed from four primary grinding units. A section consists of six 9-cell 61-cu ft roughers and six 3-cell 61-cu ft cleaners. These mechanical flotation units develop air and circulate the pulp for aeration by the action of concentric rubber-covered squirrel cages. The rotating inner cage has opposing impellers at top and bottom whose pumping action forces the pulp out between the rubber rotor posts. The vortex formed by the upper impeller draws air into the pulp. Aeration is accomplished by the mixture of air and pulp being forced out through the openings between the rubber stator tubes. A conical perforated rubber skirt, which surrounds the stator, disperses the pulp flow. The aeration units operate in long tanks, each tank having a single set of control gates and weirs. It has been found necessary to operate the rougher cells with a very high pulp level, froth depth being not more than 2 in.

Aeration units of all cells are driven through V-belts by 15-hp, 1800-rpm vertical motors. Rotor speed of the roughers is 425 rpm and speed of the cleaners 390 rpm.

Rougher flotation feed containing about 22 pct solids flows by gravity from the primary grinding units to a distributor, which contains baffles to aid in mixing the returned cleaner tailing with the new feed. The mixed feed flows through pipes to the flotation machines. Lime and collector reagent are added in the ball mill, while the frother reagents are added to the feed in the launders some distance ahead of the distributors. Provision has been made to add more lime and collector reagent in the launders ahead of the distributor if desired.

The rougher flotation machines consist of nine cells each. The primary roughers, which are the first three, are set 6 in. above the secondary roughers containing six cells. One rougher machine was altered for test purposes. The six secondary cells were raised to the same level as the three primary cells, and the control gate and weir were removed from the end of the primary tank, making one tank nine cells long. Volume changes in feed have considerably less effect on this machine than on the others, and there is an indication that the tailing assay is somewhat lower. Two other machines in the section are now being altered in this manner so that a comparison of three machines so altered can be made with three machines as originally installed.

In the original flowsheet, concentrates from the primary roughers were cleaned to a final concentrate. Concentrate from the secondary roughers, along with the cleaner tails, was reground and returned to the distributor boxes ahead of the primary roughers. The flowsheet was changed in February 1955 so that all of the rougher concentrates were reground before cleaning to a final concentrate and the cleaner tails were thickened and returned to the distributor ahead of the rougher machines.

With few exceptions, this later flowsheet has been in use since its inception. At various times a scavenger machine has been used to float the cleaner tailing, in which case the tailing from the scavenger has been sent to final tails and the concentrate has been returned with the rougher concentrate to the regrind units. No advantage in grade or recovery has been noted when the scavenger was used in the circuit.

Regrinding all of the rougher concentrates and reducing the reagents increased the grade of concentrate from 9.83 pct Cu in 1954 to 13.82 pct in 1955. The concentrate in 1955 contained 62.58 pct −325 mesh, compared with 54.59 pct in 1954, and the moisture increased from 7.5 to 8 pct. There was no appreciable change in recovery of precious metals (gold and silver).

Various reagents have been tried. Best average results have been achieved with sodium Aerofloat as a collector and Dowfroth 250 as a frother.

On each shift there is an operator for each of the two flotation sections. An assistant shift boss supervises all flotation. One sampler on each shift observes the operation of the automatic sampler system, changes sample buckets, and takes hand samples when required. He also prepares hourly samples of heads, concentrates, and tails for assaying. Copper determinations are made on the hourly samples by a mill assayer and are available to the operators about 45 min after the samples are taken.

Regrinding is done in four 8x12-ft ball mills driven at 20.5 rpm by two 400-hp and two 350-hp 150-rpm synchronous motors. Each mill is in closed circuit with one duplex submerged spiral classifier, set on a slope of 3¼ in. per ft and running at 4 rpm. A mixture of 50 pct 1-in. and 50 pct 1-in. balls is used in these mills. Volume of feed to the regrind mills varies from 3500 to 6000 tpd, depending on tonnage and grade of the new mill feed. On the average, each mill produces 9.5 tons of −325 mesh material per hr regardless of feed rate, which gives large variations in the percent of −325 mesh in the cleaner flotation feed.

Since one classifier per mill proved inadequate, a 12-in. cyclone was added to each regrind unit. The new feed to the circuit is pumped to the cyclone at

Flotation section comprises six 9-cell 61-cu ft roughers and six 3-cell 61-cu ft cleaners. Mill assayer checks samples of heads, concentrates, and tails hourly. In 1955 regrinding all rougher concentrates and reducing reagents produced a concentrate of 4 pct higher grade.

about 18 psi. The cyclone underflow feeds the ball mill, which is in closed circuit with the classifier. The cyclone overflow (about 33 pct of the new feed) joins the classifier overflow and is laundered to the cleaner machines. Experimental work is being conducted on the regrind units to increase their efficiency.

Concentrate Handling: Final concentrate pulp containing about 20 pct solids from the cleaner machines flows by gravity to a junction box and thence to one of two 125-ft torque thickeners. Thickener underflow is maintained at about 65 pct solids by rubber orifices fitted into pipe caps on the end of the two 3-in. pipes running from each thickener to the sump in the filter plant. Three-inch plug valves stop the flow of pulp while orifices are being changed.

The filter plant is equipped with five 11-ft 6-in. x 18-ft drum-type filters, three of which are maintained for operation. There are three rotary vacuum pumps, each with a rated capacity of 2300 cfm at 20.7 in. of mercury at 24.7 barometer. The rotary vacuum pumps are direct-driven at 495 rpm by 100-hp motors. Two small positive pressure rotary blowers are available to provide air at 1.5 psi for the discharge of the filter cake. Vacuum on the filters is maintained at 19 to 20 in. Each vacuum pump has its own exhaust pipe to prevent blow-back and condensation in the pumps that are not operating.

Owing to the nature of the concentrates, there is excessive corrosion of steel parts on the filters. The steel caulking strips are being replaced with strips of stainless steel, and experimental rubber grids are replacing the wire mesh backing for the cloth.

During the early days of operation, cotton filter cloth was used. This deteriorated rapidly and was replaced with nylon. All fabrics tried blind quickly, and covers can be used for only about 30 days. Washing covers with various solutions has not proved successful.

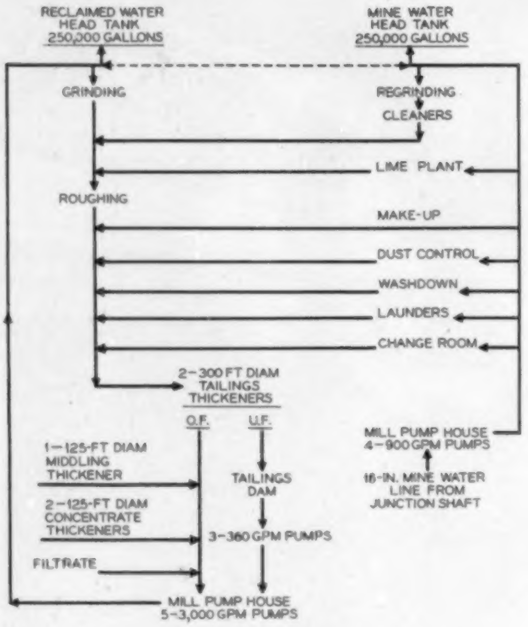
Thickened pulp was originally circulated by a pump through the plant and back to the sump through a 4-in. pipeline, but line plugging caused difficulty in changing feed from one filter to another. A distribution box was therefore installed from which the pulp can flow by gravity to each filter. The pulp is now pumped to this box from the sump. An overflow returns excess pulp to the pump sump.

One filter is normally enough to handle the feed, but two are sometimes run when the cloths become blinded or when the feed rate is excessively high.

The filter cake discharges onto a 30-in. conveyor and then to an inclined 24-in. conveyor that delivers it to the loading shed. The car loading arrangement consists of a 24-in. belt conveyor with a tripper car and a reversible shuttle belt. A track on each side of the tripper car belt holds 12 concentrate cars each. On each shift there is a concentrate crew consisting of one filter operator, one helper, and a tripper car operator. Operating data are given below:

	Sept. 1, 1954 to Jan. 1, 1955	1955	1956 to July 1
Dry tons product per filter day	776	763	1,021
Moisture in product, pct	7.50	8.00	8.30

Water Supply: Fresh water is pumped from the underground operations and flows by gravity from the junction shaft collar to the mill pump house. Domestic water is purchased.



Water Supply

Fresh water consumption averages 209 gal per ton of ore milled. This quantity varies considerably for individual months, depending on the amount of water reclaimed from the tailing pond. In 1955 fresh water consumption per month ranged from 187 to 249 gal per ton of ore milled. Average ratio reclaimed to fresh water is about 4 to 1. When 16,000 tpd of ore are treated, total water consumption is about 16.4 million gal, of which 3.3 million gal are fresh water and 13.1 million gal reclaimed.

There is an average of 22 pct solids in the mill tailings or tailing thickener feed, and the underflow is discharged at 43 to 49 pct solids depending on the slime level. Two 300-ft diam traction thickeners provide a settling area of 141,372 sq ft, or 9.4 sq ft per ton of tailings.

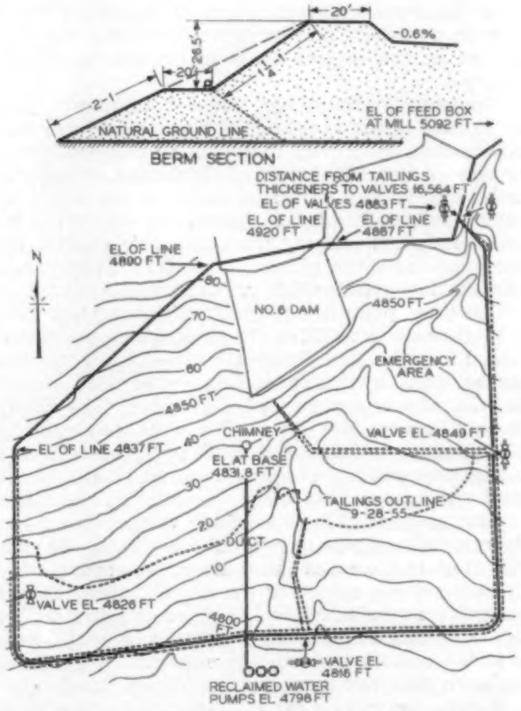
One pump operator and one thickener operator are employed on each shift.

Tailing Disposal: The tailings disposal site, about 3 miles southeast of the plant, permits gravity flow. As bounded by berms it covers 350 acres. The northeast corner of the area, where a class 100 18-in. Transite line splits to circle the pond, is 16,560 ft from the feed box at the mill, and 209 ft lower. The line from the feed box to the wye follows the natural ground elevations and has an average grade of 1.24 pct, the elevation at the feed box being 5092 ft and at the wye 4883 ft. The line as it leaves the feed box has an inverted syphon, the bottom elevation of which is 5061 ft at a distance of 1240 ft from the box. The pipe then rises to 5071 ft at 2800 ft from the box. Four-inch Crispin air and vacuum valves are placed at strategic locations to prevent air locks.

The tailing disposal line from the feed box to the wye at the pond is made up of 16-in. steel pipe for the first 225 ft; then 10,400 ft of 18-in. concrete pipe, which is buried or incased in steel tubing where it passes under railroad spurs; and 5835 ft of 18-in. Transite for the remaining distance to the wye where the pipe is above surface. When laid on surface, the Transite pipe is anchored in place by steel rods driven into the ground and wired across the top. These anchor rods are spaced two rods per pipe length.

Three 8-in. 100-hp tailing booster pumps were installed in the pump house, and a 16-in. bypass line was provided in anticipation of difficulties in clearing the line after shutdown periods. The pumps were used many times, but insufficient capacity resulted largely from air locks in the disposal line. Spigot lines were then extended about 50 ft from the portal of the tunnel to a circular steel tank to provide a 7-ft head at the intake. This added head and air vent valves on the upper end of the 18-in. disposal line corrected the early difficulties, and the sludge pumps are no longer needed.

The initial berm as built follows contour 4800 on the south side of the pond. This berm was built level on top at elevation 4815, or about 15 ft above the ground line. The south berm is 5400 ft long. The 4815 elevation was maintained in a northerly direction on both the east and west berms to points where the 4815 elevation was 5 ft above ground line. For the remaining distance both the east and west berms were built 5 ft high above the natural ground profile. The pond is bordered on the north by the tailing ponds of the old Warren concentrator. The ground on the west half of the area rises to the north with a grade of 2.2 pct and on the east half at an average grade of 1.4 pct. An east-west berm was built 1950 ft north of the south berm, tying into the old ponds. This berm extends 2750 ft from the east side of the pond with a top elevation of 4842 ft. (Average height above ground is 13 ft.) This gives an area of roughly 66 acres in the northeast corner of the pond for use in emergencies.



Tailing Disposal Area

Summary of Operating Results

Item	Sept. 1, 1954 to Jan. 1, 1955	1955	1956 to July 1
Ore treated, dry tons	1,283,050	4,556,552	2,758,503
Moisture, pct	2.1	2.3	2.3
Dry tons per operating day	11,664	14,699	16,226
Dry tons per mill per 24 hr	1,758	2,042	2,121
Available operating time, pct eight primary mills	82.92	89.99	95.64
	Assays		
Feed, pct			
Total copper	0.952	1.039	1.107
Oxide copper	0.056	0.054	0.050
Concentrate, Pct			
Copper	10.223	13.820	13.100
Insoluble	4.96	4.00	4.33
Moisture	7.5	8.0	8.3
Tailing, Pct			
Total copper	0.177	0.224	0.247
Sulfide copper	0.129	0.179	0.207
Ratio of concentration	12.970	16.683	14.952
Extractions, Pct			
Total copper	82.83	79.72	79.17
Sulfide copper	86.66	82.88	81.67
Fresh water, gallons per ton of ore	241	208	209
Average primary grind, +65 mesh, pct	6.6	5.5	5.4

The 18-in. pipe surrounding the pond has 4-in. nipples and plug valves on 65-ft centers. The nipples are screwed into saddles that are strapped to the 18-in. line. Either or both 4-in. light-weight steel or Carlon pipe, along with a 54-in. length of 4-in. rubber pipe, are connected to the nipples and together with victaulic couplings to distribute the tailings in the pond. Two 16-in. gate valves are located at the wye to run tails in either direction around the pond. Three other similar valves—one at the temporary north-south berm, one about 750 ft north of the southwest corner of the pond, and one at the east end of the emergency area berm—are used to back-pressure the line and also to place tails in different parts of the pond.

Tailings were first deposited in the pond on June 20, 1954, along the east and south berms. A total of 1,095,112 tons of tails in 124 operating days filled this portion of the pond. No water was reclaimed until September, when 15 gal per ton of mill feed were pumped.

With the filling of this area, the tails were turned into the emergency area and distributed along the east berm. Nine days later the dragline started raising the berm along the south and east sides of the pond. A temporary berm was also built running north and south 2250 ft west of the southeast corner of the pond to prevent wetting of the western half of the pond when tails were being deposited in the east half, and vice versa. This temporary berm will be discontinued when the elevation of the berm surrounding the pond is sufficiently high to push the water far enough toward the center of the area to prevent wetting the berm building sands.

Building of berm is accomplished with a 1½-yd dragline. The berm is raised about 6.5 ft per lift, a height determined by the amount of sand that can be reached with the dragline. The berm is built in two layers, the dragline compacting the first layer as it builds the second. To prevent slime from accumulating at the berm, two D-4 tractors equipped with U dozers backfill the trench made by removal of sand in building the berm. The top of the berm is made 14 ft wide to support the dragline. The slope of the sides is 1.5 to 1. Present plans are to raise the berm four times, or about 26.5 ft, and widen the top to 20 ft to accommodate the 18-in. line in its raised position and also allow width for an access road.

In elevating the pipe to its new location, it is planned to raise three lengths of pipe (about 39 ft) at a time, using the dragline as a crane and utilizing a beam with slings. Every fourth Transite coupling will be cut with a Skilsaw, using tungsten carbide-tipped saws. The sections will be fastened together again, using the same couplings encircled with steel band clamps. Either cast iron ells and Transite pipe or rubber pipe will be used to connect the pipe on the upper level with that on the level below. It is expected that the pipe will be raised in sections between the 18-in. valves so that operations will not be interrupted.

The tailings, as deposited in the pond, assume a slope between 0.6 and 0.7 pct, and there is reasonably good sand slime separation, so there is very little difficulty encountered by the dragline. Depending on weather, the time required for sand drying after moving out of an area varies from two to four weeks. Normally the dragline can begin work within a week or so, but the tractors usually have to wait somewhat longer before backfilling. In backfilling, the tractors take 6-in. cuts off the top of the sands, moving longitudinally along the area. This breaks up the crust on top of the sands and allows the moisture to evaporate more readily.

When 14,000 to 16,000 tpd of ore are treated, from 13 to 16 4-in. spigots are required to deliver tailings into the pond. The solids in the tailings are varied from 43 to 49 pct, depending on the slime level in the two 300-ft traction thickeners used for thickening the tails. Three 8-in. lines from each thickener deliver the underflow to the tailing feed box. At the tailing feed box, each 8-in. line is fitted with a plug valve and an orifice valve. The orifice valve is used to control flow volume into the box and tailing line.

The water recovery system consists of a concrete chimney 3 ft diam by 15 ft high, located about in the center of the pond. This chimney is connected to the sump at the pumping station 2000 ft to the south with a flume of 18-in. Transite pipe incased in concrete. The top of the flume has 8-in. diam holes with concrete plugs every 33 ft for reclaiming the water until the area is developed to the point where the water can be reclaimed through the holes in the chimney. Three 360-gpm vertical turbine pumps with 50-hp motors running at 1760-rpm return the water through a 10-in. Transite pipe to the concentrator. This Transite line, made up of class 200, 150, and 100 pipe, follows the tailing line back to the concentrator.

The highest recovery of water from the pond to date for any one month has been 20 pct of the water in the tailings. It is expected that after the area is sealed with slime this recovery will increase to 30 pct or better.

The tailing dam crew is made up of one operator and two helpers on day shift, one operator and one helper each on afternoon and graveyard shifts, and a boss. This crew distributes the tailings to herd the water and prevent slimes from entering the reclaim water flume. They also operate the reclaim water pumps. When it is necessary to move a considerable number of the 4-in. pipes carrying the tails up and over the berm, mill repairmen supplement the tailing dam crew.

The berm building crew consists of one dragline operator and two bulldozer operators. This equipment is serviced by the pit shops.

L-P-F Treatment of Ray Ore

by A. W. Last, J. L. Stevens, and L. Eaton, Jr.

COPPER ore from Kennecott Copper's Ray mine, about 60 miles southeast of Phoenix, Ariz., is concentrated at the company's mill at Hayden, some 18 miles south of the mine. The Hayden mill is currently treating 16,000 tons of ore per day by flotation, using raconite, a crude butyl xanthate, as a collector for the sulfide copper minerals and lime as a pyrite depressant.[1]

The ore contains significant amounts of nonsulfide copper minerals, but recovery of these values has been low. The Hayden mill is now being modified to provide for treatment of future ores by leach-precipitation-flotation (L-P-F). This modification, costing about $5 million, is expected to reduce the loss of nonsulfide copper values and improve overall copper recovery by an additional 2 lb per ton of ore.

Mineralogy of the Ray Ore: The Ray orebody consists principally of schist, with intrusions of quartz-porphyry and diabase.[2] The schist and porphyry ores are partially oxidized and because of their relatively high nonsulfide copper content will provide the major portion of the feed to the newly installed L-P-F process. Oxidation of the diabase ore is less pronounced and L-P-F treatment to improve copper recovery is not warranted, but since diabase contains appreciable pyrite needed in the L-P-F process, diabase ore will make up a portion of the mill feed.

The principal copper mineral in the schist and porphyry ore is chalcocite, while the principal copper mineral in the diabase is chalcopyrite. Nonsulfide copper minerals account for about 20 pct of the copper in the schist ore. In order of importance, the nonsulfide copper minerals are copper silicates, cuprite, malachite, tenorite, and native copper. Present flotation practice will effect a reasonable recovery of cuprite, which is generally closely associated with the chalcocite. The L-P-F process is aimed primarily at recovering copper that occurs as carbonates, silicates, and sulfate.

Development of the L-P-F Process: When Kennecott's Western Mining Divisions Research Center was established in 1952, a major problem was to improve copper recovery from the Ray ore. No economical method of increasing recovery by flotation of the silicate and carbonate minerals was developed. However, an L-P-F process was developed that improved copper recovery significantly. Laboratory test results were confirmed by continuous pilot mill tests, and it was decided to modify the Hayden concentrator for L-P-F processing.

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The L-P-F process is not new. The basic steps of leaching nonsulfide copper minerals with sulfuric acid, precipitating the dissolved copper as a metallic sponge, and recovering the sponge copper by flotation have been known for many years. Early attempts to use L-P-F met with only limited success, primarily because shredded iron was used as the copper precipitant. Shredded iron will effectively precipitate copper from solution, but since there is no practical method of carrying an excess of this precipitant through the process with the flotation pulp, it is not possible to prevent re-solution of the copper sponge during flotation. The successful application of L-P-F today, as illustrated by Anaconda's L-P-F treatment plant,[3] is largely the result of technical advantages gained by the use of finely divided sponge iron and the development of an economical method of producing this precipitant from pyrite calcine.[4] The use of sponge iron permits establishment of a circulating load of precipitant throughout the precipitation, conditioning, and flotation circuits, thus preventing re-solution of the copper sponge. Because of this protection against re-solution, it is possible also to adjust the acidity of pulps for optimum leaching and flotation efficiency rather than for minimum rate of re-solution of precipitated sponge copper. Additional advantages of using sponge iron are complete and rapid precipitation of copper and the formation of a flocculated sponge copper that responds readily to flotation. Production of sponge iron is an essential feature of the L-P-F process.

Laboratory testing showed that for optimum metallurgical results in the L-P-F treatment of Ray ore, the ore should be crushed to pass 3 mesh, leached with sulfuric acid, and then deslimed at 200 mesh. By this treatment, the bulk of the nonsulfide copper minerals could be dissolved in 10 min and the amount of solids to be treated in an acid flotation circuit held to a reasonable fraction of the ore. Laboratory testing showed that an average of 8.0 lb of sulfuric acid and 4.0 lb of metallic iron were required per ton of ore treated. Precipitation of the dissolved copper was quite rapid—with a moderate excess of sponge iron, the copper in solution was reduced to less than 0.01 g per liter in 5 min. The indicated optimum flotation conditions were a pulp density of 15 to 18 pct solids and a pulp pH of 3.8 to 4.0, with Minerec A as the collector and pine oil as the frother. Under these conditions the copper sponge floated very rapidly; however, the fine chalcocite floated more slowly and a total flotation time of 13 min was indicated for good overall copper recovery.

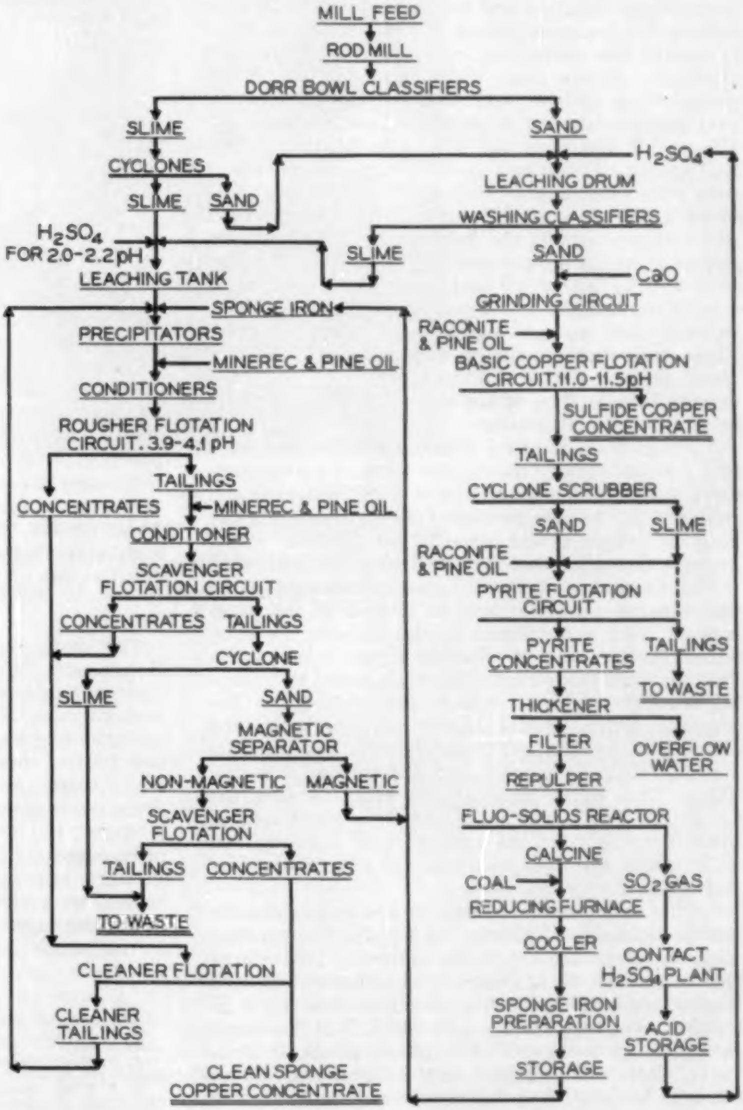
Flowsheet for the Hayden L-P-F Installation: A simplified line flowsheet for the L-P-F process now being installed in the Hayden mill is presented here.

The L-P-F process has been designed for minimum interference with the present grinding and flotation circuits. In fact, provision has been made to use the present sulfide flotation process exclusively during a prolonged period of mining ores of low nonsulfide copper content.

Four parallel grinding and classifying circuits are employed in the Hayden mill. In each circuit the mill feed is reduced to −3 mesh in 9x12-ft rod mills. The L-P-F process begins with this rod mill product. The rod mill discharge will be deslimed in 24-ft Dorrbowl classifiers with the overflow product further treated in cyclones to reduce to a minimum the amount of contained +200 mesh. The slime product from the four mill circuits will be combined and pumped to a single 40-ft diam slimes leaching tank. In each circuit, the Dorrbowl classifier sands, at about 80 pct solids, will feed a 12x20-ft leaching drum, to which 6 to 10 lb of sulfuric acid per ton of feed will be added. The leaching drums are lined with rubber and acid-brick and have a spiral pattern of brick lifters. The leaching drums revolve at 4.23 rpm and have a nominal pulp retention time of 10 min. The leach solution will be maintained at a pH of 1.5 to 1.7 in the leach drums.

The solids from the leaching drum will be washed countercurrently in two acid-proof Dorr QSHX classifiers operating in series. Space has been provided for installation of a third classifier in the series if it is needed. Acidic, copper-bearing pulp overflowing the washing classifiers will be pumped to the slimes leaching tank, where it will combine with the slime overflow product of the 24-ft Dorrbowl classifiers. Leached and washed sand will enter the existing alkaline grinding circuits and after grinding will report as feed to the sulfide copper flotation circuit and the pyrite recovery unit of the L-P-F installation.

The feed to the acid (or slime) flotation circuit, consisting of overflow products from the Dorrbowl and washing classifiers, will amount to about 3700 tpd of solids. Approximately 95 pct of the solids in this circuit will be −200 mesh. In the slimes leaching tank dissolution of the nonsulfide copper minerals will be completed. If necessary further acid will be added to maintain a pH of 2.0 to 2.2. Con-



L-P-F (Leach-Precipitation-Flotation) at Hayden Plant

Pilot Mill Results with L-P-F Processing of Ray Ore

Sample Heading Analyses

Cu (Total), Pct	Cu (Nonsulfide), Pct*	Fe, Pct
1.178	0.340	5.80

Metallurgical Results with Conventional Sulfide Flotation

Shift	Heading Cu, Pct	Concentrate Cu, Pct	Tailing Cu, Pct	Recovery Cu, Pct
A	1.10	32.12	0.41	63.5
B	1.20	25.49	0.42	66.1
C	1.19	27.46	0.42	65.7
24-hr average	1.16	28.36	0.42	65.1

Metallurgical Results with L-P-F Processing

Shift	Heading Cu, Pct**	Concentrate Cu, Pct**	Tailing Cu, Pct*	Recovery Cu, Pct
A	1.20	30.32	0.18	85.6
B	1.13	28.21	0.19	84.2
C	1.13	23.15	0.20	83.5
24-hr average	1.15	27.23	0.19	84.4

* Determined by leaching with NH_3-$(NH_4)_2CO_3$ solution.
** Calculated.

centration of copper in solution will vary with the quantity and occurrence of nonsulfide copper minerals in the mill feed but will average 1.25 g Cu per liter.

The leached slime pulp will be distributed to four parallel precipitation and flotation circuits. Dissolved copper will be precipitated by successive additions of sponge iron reclaimed from flotation tailings and of virgin sponge iron, which will be fed to the precipitation cells as −35 mesh powder. Following precipitation the pulp will be conditioned with Minerec A and pine oil. The acid flotation circuit will consist of rougher, conditioning, and scavenger cells with rougher and scavenger concentrates combined for single-stage cleaning. In the precipitation and flotation circuits the pulp density will be maintained at about 18 pct solids. The pH of flotation feed will be 3.8 to 4.0 and total flotation time 13 min. Concentrates recovered from the circuit will contain both sponge copper and fine chalcocite. These concentrates will be combined with concentrates from the basic sulfide flotation circuits, and enough lime will be added to neutralize any excess acidity before dewatering.

Tailings from the acid flotation circuits will contain residual sponge iron in the form of coarse middling grains. This sponge iron will be recovered and returned to the precipitation cells by desliming the pulp in cyclones and passing the cyclone spigot product through a belt-type wet magnetic separator.

The leached and washed sand discharged from the washing classifiers will be ground in the presence of lime and treated in the existing flotation circuit for recovery of a sulfide copper concentrate. Tailings from this circuit will be scrubbed by pumping through cyclones, which will reduce the depressant action of the highly alkaline pulp and allow recovery of a pyrite concentrate in a separate alkaline flotation circuit, using raconite as a collector. This pyrite concentrate, assaying 40+ pct Fe, will be pumped to the sponge iron plant located some distance from the concentrator building and will supply the raw material for manufacture of sulfuric acid.

At the sponge iron plant the pyrite concentrate will be thickened, filtered, and repulped to produce a slurry of controlled water content. This slurry will be fed to a 22-ft FluoSolids reactor and roasted to produce a calcine containing less than 1 pct S. Calcine, at a temperature of 1100°F, will discharge directly into two parallel 10x30-ft Bruckner furnaces. Coal will be added to the furnace to reduce the iron to metal and the charge will be heated to 1800° to 1900°F by gas burners at the discharge end of the furnace. At this temperature the calcine will be reduced to a porous metallic iron product. Sponge iron discharged from the Bruckner furnaces will be cooled to less than 150°F in a single Baker cooler before being exposed to air. The cooled sponge will be separated magnetically from coarse residual coke and crushed to −35 mesh in a 4x6-ft dry rod mill. Laboratory data indicate that sponge iron assaying 55 to 60 pct metallic iron should be produced.

A portion of the SO_2 gas produced by roasting the pyrite will be diverted to a standard 100-tpd contact sulfuric acid plant. Sulfuric acid will be transported by pipeline from storage tanks at the acid plant site to the concentrator building.

Metallurgical Results: The L-P-F technique was studied in considerable detail in laboratory tests to determine average metallurgical results and average increase in copper recovery and to establish process requirements. These laboratory tests indicated that L-P-F processing of *average* Ray ore, containing 0.27 pct nonsulfide copper, would recover 2.0 lb more copper per ton of ore than the flotation process in use at the Hayden concentrator. Laboratory test results were confirmed in a series of continuous pilot mill tests in which six samples of ore, totaling 250 tons, were treated by L-P-F in a series of 10-day, 24-hr tests. In these tests the increase in copper recovery varied from 1.35 to 4.46 lb per ton of ore, depending upon the nonsulfide copper content of the sample. Average increase was 2.55 lb per ton and average nonsulfide copper content of the ore samples 0.33 pct. For *average* schist-type Ray ore, containing 0.27 pct nonsulfide copper, increased recovery of 2.0 lb Cu per ton was indicated, in agreement with batch laboratory test data.

Table I presents a direct comparison between metallurgical results obtained by L-P-F and by conventional sulfide flotation. In this pilot mill test a sample of Ray ore of higher than average nonsulfide copper content was treated both by L-P-F and by conventional sulfide flotation, using raconite and a high-lime circuit corresponding to Hayden practice. With this particular sample of ore, L-P-F processing increased copper recovery from 65.1 to 84.4 pct, an increase of 4.3 lb Cu per ton of ore. These results, typical of those obtained in tests with highly oxidized samples of Ray ore, illustrate the effectiveness of the L-P-F process.

Acknowledgments

The work reported was a cooperative effort of Kennecott's Western Mining Divisions Research Center, Engineering Div., and Ray Mines Div. The authors wish to acknowledge the assistance of all research and engineering personnel who worked on this project, particularly A. E. Back, who directed the research work on production of sponge iron. They express appreciation to A. P. Morris, general manager, Ray Mines Div.; S. R. Zimmerley, director of research; and S. D. Michaelson, chief engineer of Western Mining Divisions, who supported and directed the various phases of the project. They also thank the management of Kennecott Copper Corp. for its support and for permission to present this article.

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Tin Mining in Malaya

by H. D. Kiddle

On Aug. 31, 1957, Malaya received her independence and became a full member of the British Commonwealth. This article describes the importance of tin mining in the country's economy.

TIN mining in Malaya has been a courageous adventure in private enterprise, attended by all the hazards of prospecting in unexplored areas of tropical jungles—jungles that still cover four-fifths of the country.

To assess the contribution of an industry to a country's revenue, it is necessary to consider not only duties levied on the products, but also the revenue from all businesses and individuals directly and indirectly deriving income from the industry. Exact figures are not obtainable, but from 1850 until shortly before the first World War, tin mining in Malaya was a dominant factor in the Federation's development. Even at the turn of the century, tin export duty alone represented 45 pct of total Government revenue, while in the 40-year period up to the end of 1937, tin ore duties collected by the Federated Malay States Government amounted to 383,810,284 Malayan dollars,* approximately one-fifth of the total revenue for the same period.

The importance of tin mining in the recovery of the country after World War II can be gathered from the fact that from 1946 to 1953, in spite of the work of rehabilitating Japanese occupation ravages, and at the same time combatting the activities of Communist terrorists, the industry provided Government revenue with 333,500,000 Malayan dollars in export duty alone.

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* One Malayan dollar equals 33 U.S. cents.

Since first use in 1912, dredges have been highly efficient in working water-plentiful areas of Malaya. This floating mill near Kuala Lumpur mines and processes tin ore for Selaying mines.

Early Mining Records: The presence of tin ore in the Malay Peninsula apparently has been known from very early days. Records indicate that the Ptolemies knew of these deposits at the time the first Cornish tin mines were being worked. It is much more certain that the Chinese have been working these deposits for the last several centuries; their records of the early 15th century speak of tin being found in the mountains and of men being sent to mine it. D'Albuquerque, the Portuguese conqueror of Malaya, mentioned the substitution of his own currency for Malay coinage. Both coinages were made of tin.

Later Chinese records mention tin exports from Johore and Pahang, and the Dutch in the 17th and 18th centuries endeavored to keep a monopoly of the tin produced in Kedah and Perak. In 1879 tin mining received an impetus from the rapidly growing demands for the metal by both the U. S. and the United Kingdom for the production of tin plate. In the 1880's Europeans entered the industry, bringing new techniques and mechanical mining devices.

New Phase of Development: In 1912 bucket dredges were first installed in Malaya and were operated successfully. As a result there was a great increase in the flow of overseas capital into the industry, which entered a new phase of development.

During the last 150 years, in spite of the entry of new countries into the field of tin production, Malaya has consistently maintained her position as the largest single tin-producing country, contributing more than a third of the Free World's supply.

Tin mining in the Federation of Malaya at the present time may be divided into the following categories: dredging, gravel pump mining, hydraulicking, open cast mining, lode mining, and dulang washing or panning.

An important percentage of the country's output of tin oxide is won by the bucket dredge. Where tin oxide is found in an alluvial deposit in large and comparatively level areas of deep and sometimes swampy ground, dredging is often the only efficient or economic method. The modern bucket dredge is capable of digging and treating a very large volume of ground quickly and at low cost.

The tin dredge is an excavator made up of an endless chain of steel buckets, together with a concentrating plant for treating the spoil raised by the buckets. The entire equipment is mounted on a floating pontoon in a pond or paddock, supplied with water from the nearest source. Comparatively few dredges work in natural bodies of water, although there are dredges operating in seas near the coast.

Nearly 80 dredges are at work in the Malayan tin fields. Older dredges may be driven by steam (many have been converted to electricity in recent years) with buckets of 4 to 10-cu ft capacity, capable of digging 40 or 50 ft below water level. The more modern dredges are all-electric and may have 15 to 20-cu ft buckets with a digging depth of as much as 135 ft below water level.

Introduction of the large-capacity deep-digging dredge in the Asian tin fields before World War II has made it profitable to dredge alluvial areas where tin oxide has been found deposited at depth. However, since it may cost £1 million ($2.8 million) to install a dredge complete with ancillary equipment, and since this capital expenditure must be recouped out of profits, it is essential that the low grade area be extensive enough to provide a reasonable operating life for the dredge and that the price of tin remain stable at a reasonable figure.

The product of the dredge jigs is a black sand containing 20 to 60 pct tin oxide, which is taken off the dredge to a tin dressing plant for final cleaning and drying; this process is usually aided by modern mechanical concentrating equipment, such as magnetic and electrostatic separators, classifiers, shaking tables, and screening equipment.

Pumping Systems: The gravel pump mining method is chiefly employed on alluvial deposits where the deposit is too limited in extent or the terrain too hilly for dredging. A sump or pit is formed in an excavation, and a pump supplies water to monitors or nozzles that break down the face of the excavation with jets and carry the dirt and gravel bearing the tin oxide to the sump. From the sump the material is pumped to a series of sluice boxes built on a gradient that insures a controlled flow. The crude tin oxide is caught behind stops of various depths placed across the sluice boxes and is then removed for much the same process of final concentration in the tin dressing plant as is employed with the tin oxide from the dredges.

Hydraulicking, a variant of the gravel pump method, can be used where the topography allows water to be brought to the mine pit under natural hydraulic head. The hydraulic head provides pressure for the monitors and a hydraulic lift takes the place of the gravel pump. A combination of this method and gravel pumping is sometimes found.

Methods Used When Water Is Scarce: Open cast mining is employed where water is scarce and the ground difficult to break up with hydraulic monitors. Power shovels and draglines are sometimes employed, as well as hand labor and scrapers for excavating overburden and the tin oxide-bearing alluvium. Track haulage with locomotives, belt or overhead conveyors, and pumps are often used for transporting the material for concentration in sluice boxes or jigs.

The Pahang Consolidated Co. mine is the world's largest producer of tin ore by the underground lode mining method. Underground workings comprise 200 miles of tunneling. It is an undertaking of the first magnitude.

Dulang washing or panning is done by women, who work on their own in streams and rivers, contributing some 1.5 pct of the country's production.

Nepheline Syenite At Blue Mountain

by H. R. Deeth

NEPHELINE syenite is a sodium, potassium, aluminum silicate rock occurring in many countries. Large deposits have been investigated in Russia, India, and Norway and in the U. S., where it is known to occur in Arkansas, New Jersey, and Wisconsin. There are extensive areas containing nepheline syenite in south-central Ontario, a region surveyed in 1905 by Adams and Barlow.

By 1925 considerable interest had developed in searching for aluminous raw materials that could be used by the glass industry. This finally focused attention on the nepheline syenite described by Adams and Barlow in 1910.[1]

One factor found common to the deposits of nepheline syenite was the inclusion of iron-bearing minerals that rendered the material unsuitable for manufacture of flint glass. Nevertheless, one particular deposit described in the Adams and Barlow report seemed a likely commercial source of alumina for glass making. This was a large ridge called Blue Mountain, located in Methuen Township of Peterborough County, Ont. Outstanding characteristics of this deposit were an alumina content of 24 pct, a combined alkali content of 15 pct, and an unusual uniformity throughout the deposit.

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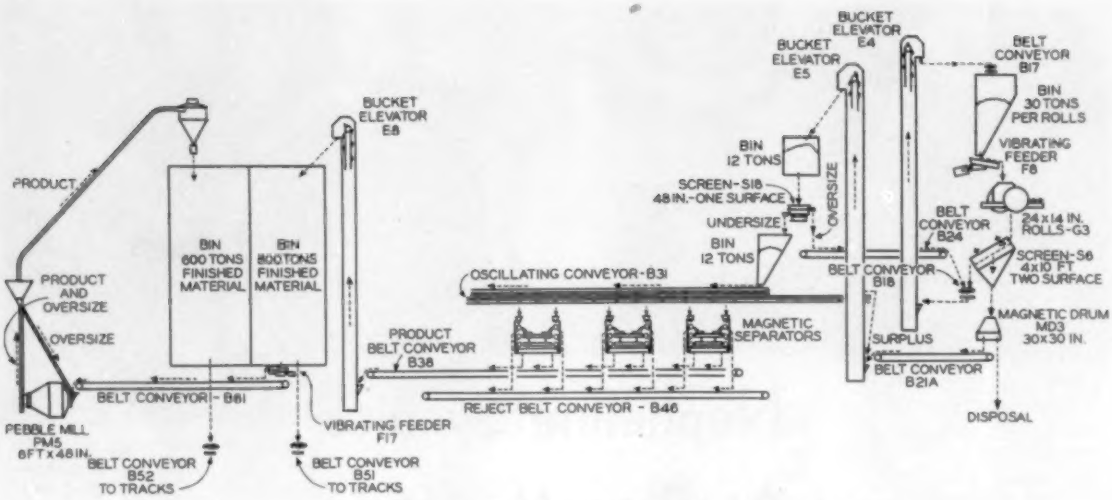
The 2 pct Fe_2O_3 content was the only detrimental feature, but rapid advances made in the field of high intensity magnetic separation during the late 1920's offered a possible solution to the problem.

Tests were carried out on high intensity magnetic separators, and when satisfactory separations were obtained samples of the refined material were submitted to glass plants for trials. This established that the Blue Mountain nepheline syenite was suitable for the glass industry.

In 1935 the first commercial shipments of Methuen Township nepheline syenite were made from a mill at Lakefield, Ont., by a company called Canadian Nepheline Syenite Ltd.[2,3] This operation, now



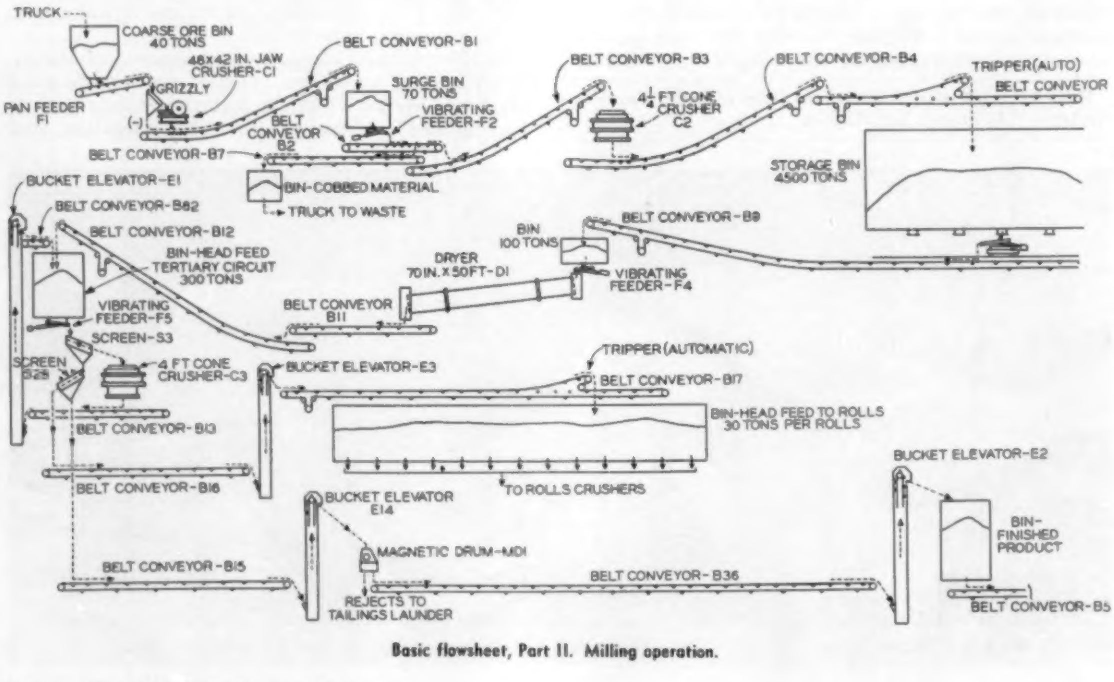
Basic flowsheet, Part I. Jaw crusher to rolls crushers.

called American Nepheline Ltd., has been the only continuous producer of nepheline syenite up to 1956. The following history of the development and production of nepheline syenite is based on the writer's association with Canadian Nepheline Ltd. and American Nepheline Ltd. since 1935.

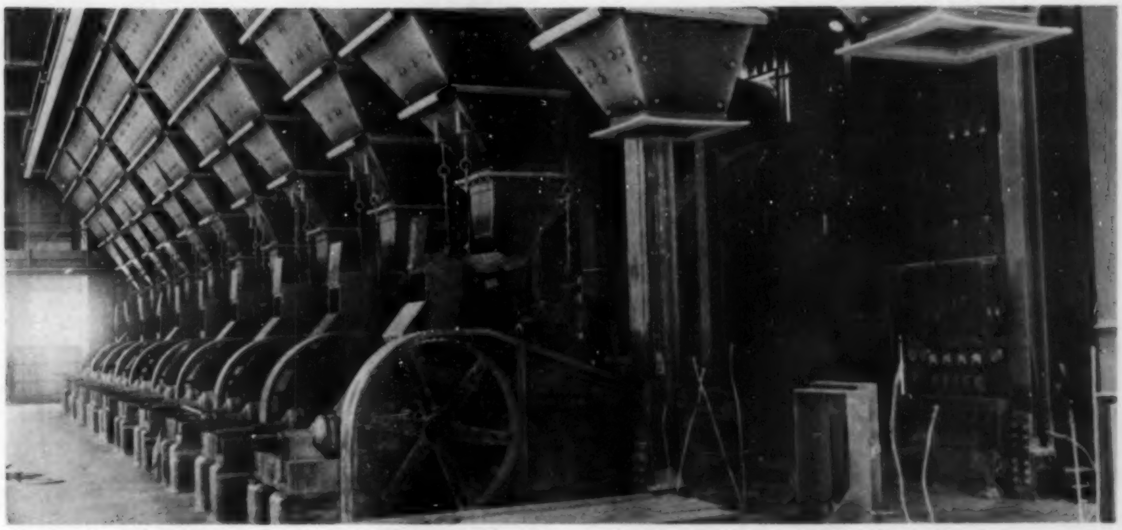
The Methuen Township deposit is a pear-shaped ridge about 5 miles long. The nepheline syenite mass is about a mile wide at the widest part and a few hundred yards at the narrowest. It reaches heights of 300 ft. On the north it borders with alkali syenite and on the south with Grenville schist.[4] This deposit is usually referred to geologically as an igneous alkaline intrusion, although other theories regarding its formation have been advanced in recent years.[5]

The nepheline syenite rock is light in color, has a fine grained granitic texture, and contains little or no free quartz. It is composed of a mixture of feldspars and the feldspathoid mineral nepheline, along with small percentages of iron-bearing accessory minerals. The following table indicates the mineralogical compositions of the rock and some physical properties of the refined product:

Approximate Mineral Composition[4]	Volumetric Percent
Albite ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$)	54
Microcline ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$)	20
Nepheline ($(Na, K)_2O \cdot Al_2O_3 \cdot 2SiO_2$)	22
Muscovite	2
Mafics (biotite, hastingsite, magnetite)	
Total	100
Physical Properties of Finished Product	
Specific gravity at 30°C	2.61
Hardness, Mohs scale	5 to 6
Refractive index (average of minerals)	1.53



Basic flowsheet, Part II. Milling operation.



An oil-fired rotary drier 50 ft long and 70 in. diam dries the ore of surface moisture to ease mill problems.

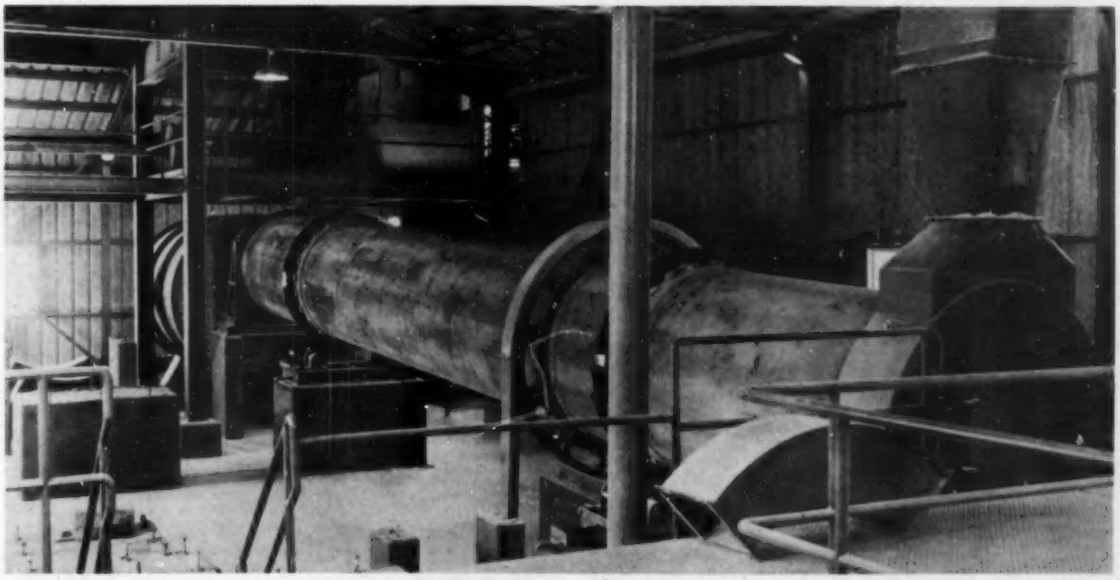
Removing the iron-bearing minerals by magnetic separation reduces the iron content from about 2 pct to an average 0.08 pct Fe_2O_3. Typical analysis of the finished product is as follows:

Element	Percent
SiO_2	60.4
Al_2O_3	23.6
Fe_2O_3	0.08
CaO	0.7
MgO	0.1
Na_2O	9.8
K_2O	4.6
Loss on ignition	0.7
Total	99.98

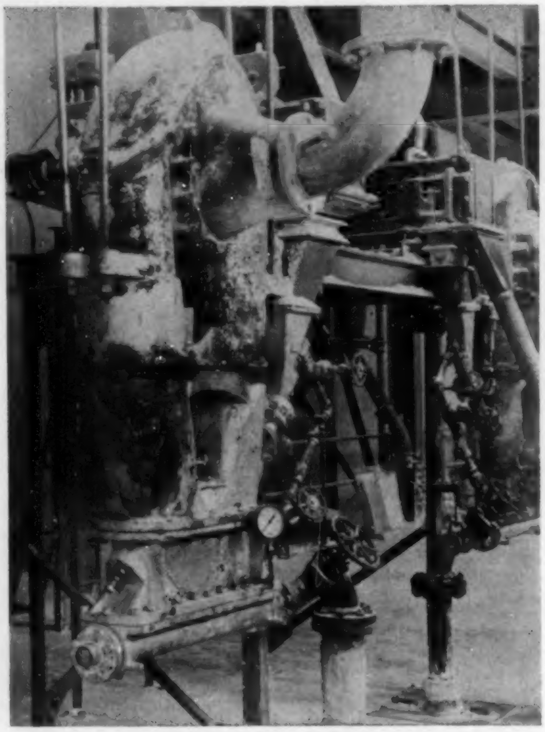
When operations started in 1935 the plant was located at Lakefield, Ont., some 110 miles northeast of Toronto and 25 miles southeast of the deposit. This location was selected because of the railroad in Lakefield and the roads available for trucking. Barging facilities during summer months decreased trucking to a distance of 4 miles from the mine to Stoney Lake.[5]

As demand increased, a larger mill was erected in 1937 at Rochester, N. Y., to supply the glass industry in the U. S.[6] In 1946 a new mill was built at the deposit in Methuen Township and the finished product was trucked to storage bins situated on the railroad at Lakefield.[6] Termination of the car ferry service from Cobourg to Rochester necessitated longer and more costly rail shipment of crude rock to Rochester via Buffalo. Economy dictated closing the Rochester plant, and the Ontario plant was expanded to provide total product requirements.

In 1954 a 17-mile railroad spur was constructed by the Canadian Pacific Ry. from Havelock to the plant location, now named Nephton, Ont. This fa-



These rolls crushers take a ¼-in. feed. In closed circuit with vibrating screens, 30-mesh material is produced.



Fluid-energy mills are used to produce the plant's finest grinds (325 mesh), used in the manufacture of pottery.

cilitated construction of a new modern fireproof plant and storage bins adjacent to the existing plant. The new plant was completed in 1956.

Mining and Processing at Nephton, Ont.: Mining is carried out by open cut methods. Several benches and faces are mined to provide flexibility in drilling, blasting, and truck loading operations.

Crude rock is trucked about 300 ft to the crushing plant, where it is discharged into a surge bin feeding a 48x42-in. jaw crusher. The 7-in. charge from the jaw crusher is conveyed to a 4½-ft cone crusher, where it is reduced to 2 in.

This cone crusher product is conveyed to a 5000-ton storage building, where an automatic distributor spreads the material uniformly across the storage pile. Requirements for milling are drawn from several points onto a conveyor beneath the storage building which transports the rock to a drying building.

All the crushed rock passes through an oil-fired rotary drier 50 ft long and 70 in. diam equipped with a wet dust collector to handle the exhaust discharge. This provides dry rock for the mill, facilitating subsequent screening and magnetic separation. Water removed by drying is chiefly surface moisture that varies in quantity according to weather conditions.

The rock from the drier is conveyed to a tertiary crusher plant in the mill building, where it is reduced to ¼ in. by a 4-ft cone crusher in closed circuit with mechanical screens. This ¼-in. material provides feed for rolls crushers in closed circuit with vibrating screens, which can remove a 30-mesh product from the circuit. At this particle size most of the iron-bearing minerals are free from the nepheline syenite and can be removed by magnetic separation. From the vibrating screens the 30-mesh material is fed directly to 30-in. low intensity magnetic drums that remove highly magnetic material, chiefly magnetite.

Product from the magnetic drums passes over scalping screens that remove any oversize and control the particle size of the final product. Undersize from these screens enters surge bins, from which material is distributed to high intensity magnetic separators by oscillating conveyors.

Each magnetic separator consists of a vertical bank of three small diameter rolls that rotate in magnetic fields, thus acquiring induced magnetic charges. Material passes consecutively over a low intensity roll and two high intensity rolls, and any feebly magnetic iron-bearing minerals are removed.

About 25 pct of the ore fed to the plant is removed as waste in the process of crushing and grinding the nepheline syenite and reducing the iron content from about 2 to 0.08 pct Fe_2O_3. These tailings are conveyed from the plant to a dumping ground.

The finished 30-mesh product is placed in storage silos, from which portions are drawn for shipments. Most shipments are made in bulk hopper cars, and tonnages in each are controlled by passing over a weightometer. A portion of the 30 mesh is drawn as feed for pebble mills for turning out 200 and 270-mesh products. A 325 mesh is also produced by grinding in fluid-energy mills. These fine grinds are used chiefly in the pottery industry.[7]

Throughout the operation, from quarry to finished product, a constant check is maintained by a quality control department to insure uniform products of high quality.

Geological surveys and diamond drilling indicate many tons of nepheline syenite in the 2500 acres of the deposit owned by American Nepheline Ltd. This rock, as it occurs, has a remarkable chemical uniformity and only slight mineralogical variation. The quality control program within the process insures maintenance of finished products within carefully established specifications.

This description has been limited to production of nepheline syenite by American Nepheline Ltd. from 1935 to 1956. In 1956 a second company, International Minerals and Chemical Corp. (Canada) Ltd., commenced operation of a mill at the northeast end of the same deposit in Methuen Township, Ont. The Methuen Township nepheline syenite deposit is the only one providing a low iron product for industrial use. A deposit of nepheline syenite is being mined in Arkansas for production of roofing granules, but the products are all relatively high in iron. Other than these, there are no known deposits of nepheline syenite being worked commercially in the Western World.

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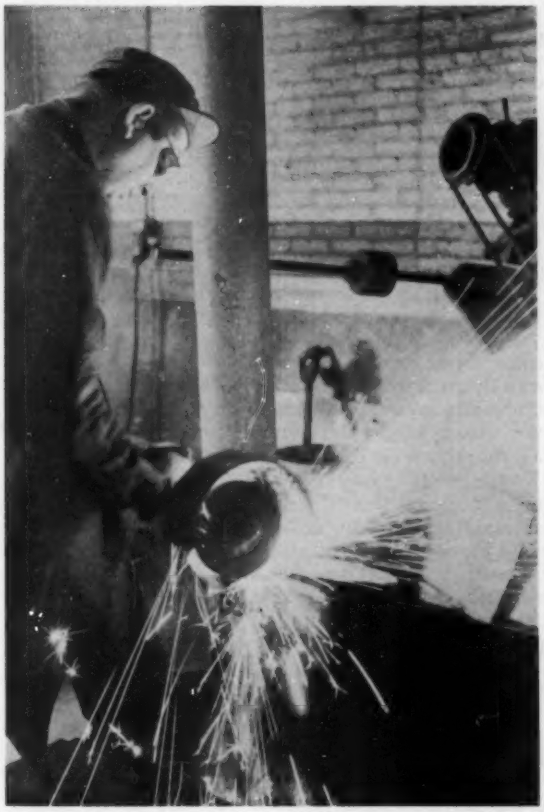

Titanium and Zirconium, Twin Metals of the Atomic Age

by K. C. Li

TITANIUM, because of its high strength, weight ratio, and high melting point, became the metal of the jet age. Zirconium, because of its low neutron cross section and high corrosion resistance to hot water, became an integral part of the nuclear era. Since both metals are very similar chemically, more or less the same process is used for their production.

The sudden rise of this new industry of titanium and zirconium seems to have caused some uncertainty as to the future development of processes for making these metals. Although zirconium was discovered in 1789 and titanium in 1790, it was not until 1945, six years after W. J. Kroll patented his process, that F. S. Wartman of the U. S. Bureau of Mines perfected the technique of producing ductile titanium, and it was not until 1946 that Kroll perfected the technique of producing ductile zirconium in commercial quantities. Since then the Government and private industry have spent millions of dollars each year constantly searching for new methods, with the hope that some day titanium can be produced as economically as aluminum and magnesium or as cheaply as stainless steel.

The hundreds of patents issued on this subject need not be reviewed here. Up to the present time only three processes are used in production, and a fourth is in pilot plant scale: 1) the Kroll process and its modification, 2) the iodide process and its modification, 3) the calcium hydride process and its modification, and 4) the electrolytic process.

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Kroll Process: The Kroll process is based on the very simple chemical reaction:

$$TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$$
$$\text{or}$$
$$ZrCl_4 + 2Mg \rightarrow 2MgCl_2 + Zr \qquad [1]$$

and its success is due to the following features:

1) Because the reaction is effected under normal atmospheric pressure no bombshell or any kind of high pressure equipment is necessary.

2) The reaction temperature is below 950°C.

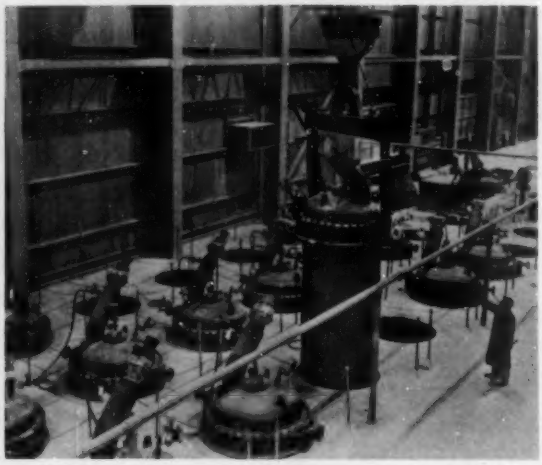
3) $TiCl_4$ or $ZrCl_4$ is used because of comparative cheapness, ease in handling, ready availability, and absence of oxygen.

4) Magnesium is used as reducing agent because of its possible high purity, ease in recycling, and freedom from alloying with titanium or zirconium.

5) Inert gas is used to protect titanium or zirconium from contamination of oxygen, nitrogen, and other gases.

6) The resulting titanium sponge is purified by vacuum distillation or is leached to remove byproduct salt.

On Sept. 15, 1954, the president of Electro Metallurgical Co. announced that the nation's largest titanium plant would use a modification of the Kroll process, by which the reduction of $TiCl_4$ is effected with sodium instead of the magnesium used in the process by other makers. In fact, Kroll's patent never did claim sodium as the reducing reagent. In 1956 National Distillers Products Corp. announced the use of sodium instead of magnesium for reducing zirconium and titanium. Imperial Chemical Indus-



First U. S. plant to use sodium reduction process on a commercial scale was this titanium sponge facility of Electro Metallurgical Co. at Ashtabula, Ohio. Here a reactor is lowered into a cooling station.

tries Ltd. in England has been producing titanium by sodium reduction since June 1955 at a smaller production capacity of 1500 tons per year.

Iodide Process: The iodide process of Van Arkel-DeBoer is also based on a very simple chemical reaction:

$$TiI_4 \rightarrow Ti + 2I_2$$
or
$$ZrI_4 \rightarrow Zr + 2I_2 \qquad [2]$$

When the compound TiI_4 or ZrI_4 in gas form contacts a highly heated material such as a filament in a bulb, this compound automatically decomposes into its components—titanium or zirconium metal and iodine.

This process is very effective in removing such impurities as oxygen and nitrogen, thus producing a pure metal. But it does not eliminate other impurities common in titanium or zirconium, such as aluminum or iron.

Since the titanium or zirconium has to decompose on the filament in a bulb and since iodine is an expensive reagent, mass production and continuous operation by this process seem remote.

In pilot plant scale many investigators have also tried to develop a continuous iodide process, as indicated in U. S. patents 2,519,368; 2,694,653; 2,714,564, and 2,694,654. The process comprises the following steps:

1) TiO_2 or ore (such as ilmenite) is reduced to TiC in an electric furnace of SiC type at 1800°C.

2) I_2 gas converts TiC into TiI_4 in a graphite-lined electric furnace at 1100°C.

3) TiI_4 is purified by fractionation-controlled cooling under vacuum—TiI_4 at 379°C; SiI_4 at 278°C; and I_2 at 183°C.

4) Thermal dissociation of TiI_4 takes place at 1100°C at 30 mm Hg on tungsten or titanium wire or surface.

5) Design of the thermal dissociation chamber determines the forms of finished product—titanium rod formed on a wire core or sheet formed on metal surface.

The bromide process is a modification of the iodide process in which the iodine is replaced by bromine.

Calcium Hydride Process: The calcium hydride process of Metal Hydrides Co. is the only method using the oxide form as starting material which is directly reduced by CaH_2 to titanium. But the product is in a powder form and usually contains oxygen and hydrogen, which are objectionable for most purposes. Its titanium content is only about 98.5 pct. Its production cost is even higher than Kroll's, because the CaH_2 or Ca is an expensive reagent. This process, therefore, may be suitable only for production of titanium powder, usable in powder metallurgy.

Although calcium has been shown to be one of the most favorable reducing agents for zirconium oxide, according to S. M. Shelton and others,[1] no commercial method has been developed to produce significant amounts of pure zirconium metal, but the crude zirconium metal made by the calcium reduction process may be suitable for refining by the iodide process in making the purest zirconium.

Electrolytic Process: The electrolytic process, using a molten salt bath containing either titanium (or zirconium) fluoride, chloride, or oxide, is still in pilot plant stage, although it has been said for many years that the Kroll process would be replaced by a cheaper, continuous electrolytic process similar to that of aluminum or magnesium. Even on a pilot plant stage there has been no success in producing ductile titanium or zirconium metal from its oxide by electrolysis because of oxygen contamination in the metal. Use of titanium or zirconium halide or complex halide compounds gives more promising results, as shown by different companies engaged in electrolytic process research. The fundamental drawback of electrolysis of titanium or zirconium compounds lies in the inherent physical and chemical properties of the metals.

First, the melting point of titanium or zirconium is about three times higher than that of aluminum. Therefore it is impossible to remove the metal from an electrolytic cell in a molten state as done in the aluminum or magnesium industry. Fine crystal deposits on the electrodes have to be removed, then leached and purified. A compact deposit is desired.

Second, the high solubility of oxygen, nitrogen, and hydrogen in titanium or zirconium, together with corrosive gases liberated during operation, necessitates costly construction of an electrolytic cell. Inert gases have to be used in these electrolytic cells to prevent contamination.

Even if difficulties in enlarging from the pilot plant to commercial production can be solved, unless suitable construction material can be had there still will be no saving in comparison to the Kroll method or its modification of sodium reduction, because:

1) At the present time the electrolytic process is also a batch process.

2) Feed materials for the electrolytic process are similar to those used for Kroll's.

3) Labor cost for removing the sponge after reduction in the Kroll process is less than the cost for removing metal crystals from the electrodes.

4) Both electrolytic and Kroll processes require a salt preparation after the raw metal is formed.

Recently the USBM at Boulder City, Nev., developed an electro-refining technique for recovery of titanium from mill scrap and off-grade sponge. The quality of part of the metal thus produced is of high purity and low Brinell hardness. As this process does not liberate corrosive gases, the cell can be fabricated simply from mild steel with a spray

coating of chrome aluminum alloy. It is hoped that this technique can be developed and enlarged in such a way that commercial production will be possible.

Gross Process: Besides the four processes discussed, the Gross process created much speculation not only in the titanium or zirconium industry but also in the aluminum industry. Gross originally invented the process for making aluminum from aluminum monochloride. The reaction is as follows:

$AlCl \rightarrow Al + AlCl_3$, as mentioned in British Patent 582,579 and U. S. Patent 2,470,305. From this, similar reactions have been derived for making titanium. The following, proposed for titanium by O. Ruff of India some 30 years ago, have been reinvestigated:[8]

$$\begin{aligned} &Ti\text{-}Al + AlCl_3 \rightarrow Ti + 3AlCl \quad \text{(high temperature)} \\ &3AlCl \rightarrow Al + AlCl_3 \quad \text{(low temperature)} \end{aligned} \qquad [3]$$

$$\begin{aligned} &Ti\text{-}Al + 3Cl_2 + TiCl_4\ \text{(excess)} \\ &\rightarrow Ti + AlCl_3 + TiCl_4\ \text{(excess)} \end{aligned} \qquad [4]$$

$$\begin{aligned} &Ti\text{-}Al + 3HCl + TiCl_4\ \text{(excess)} \\ &\rightarrow Ti + AlCl_3 + 1.5H_2 + TiCl_4\ \text{(excess)} \end{aligned} \qquad [5]$$

On Oct. 9, 1956, U. S. Patent 2,766,111 was issued to Richard H. Singleton. Its highlight is as follows:

$$TiCl_4 + AlCl \rightarrow Ti + AlCl_3 \qquad [6]$$

$$AlCl_3 + Al\text{(or Al-Si, Al-Fe)} \rightarrow AlCl \qquad [7]$$

$$AlCl_3\ \text{(excess)} + O_2 \rightarrow Al_2O_3 + Cl_2 \qquad [8]$$

The reaction Eq. 6 is performed at 1300°C.

The reaction Eq. 3 is similar to the Gross process. The excess $TiCl_4$ that is not reacted in Eqs. 4 and 5 is used both to prevent the chlorination of titanium and to minimize the solution of H_2 in titanium. The reaction Eq. 7 is the Gross process.

But so far this Gross process is not known to be operated commercially anywhere. How successful the Indian process or the R. H. Singleton process will be remains to be seen. Finally, the titanium chlorides themselves also show disproportion, such as $2TiCl_3 \rightleftarrows Ti + TiCl_4$, but so far this kind of reaction has not been fully exploited.

It is obvious that the Kroll process may not be replaced by other processes in the near future. In fact, over 99 pct of the total titanium or zirconium production at the present time is made by the Kroll process or its modification, using sodium reduction.

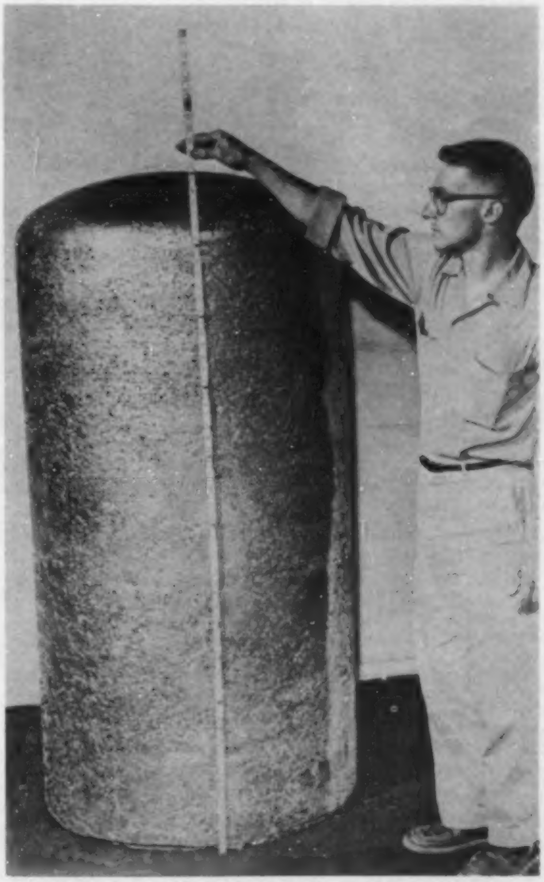
Cost Factor of Titanium: In the titanium and zirconium industry, there has been constant speculation as to whether a continuous process, either a continuous Kroll process and its modification or a continuous iodide process or electrolytic process will lead to the solution of less expensive titanium or zirconium.

In 1951 Battelle Memorial Institute developed an apparatus combining the three operations, namely, reduction, purification, and melting, into one continuous process, as mentioned in U. S. patents 2,564,337 and 2,556,763. Apparently, owing to the highly reactive and corrosive characteristics of both titanium and $TiCl_4$ at high temperature, it has not yet been put into commercial production. Neither has C. H. Winter's continuous process as patented in U.S. 2,607,674 in 1952.

The Japanese have patented a continuous Kroll process (Japan, Ishizuka Patent 5,857) which comprises an airtight chamber under the reduction retort. In this chamber several containers with perforated bottoms can be moved horizontally to receive the reduction products ($Ti + MgCl_2 + Mg$) and to separate them by heating. It is understood that this process has not yet been put into commercial production.

Recently the German Deutsche Geld und Silber Scheidenanstalt has patented a process (Br. Patent 741,630) by which titanium, zirconium, etc. are produced continuously as compact solid metal from a molten mass, without contamination, by reduction of the metal halide with magnesium or sodium. The halide and sodium are directed separately as preheated vapor streams into a reaction chamber containing an inert atmosphere. They are burned in flame that is impinged on a concave condensing surface. The condenser is held at a temperature below the melting point of the metal and above the boiling point of the halide, thus producing metals as a compact mass. For continuous operation the temperature of the collecting surface is adjusted to yield a thin molten layer of metal on the surface of the deposited layer and it is gradually drawn from the reaction chamber. The novel point of this process is that it does not involve much mechanism, but the engineering difficulties have proved formidable, and no commercial development seems likely.

As far as a semicontinuous sodium process is concerned, Kroll himself sees most promise in a two-step reduction:[8] 1) reduction to $TiCl_2$, dissolved in



Consumer demand for larger titanium forgings has led to production of huge ingots such as this 32-in. diam, 7200-lb casting by Rem-Cru Titanium. Its equivalent in steel would weigh 13,000 lb.

NaCl below 700°C; and 2) reduction of the fusible mixed salt with more sodium above 800°C. The reason is that the semicontinuous process allows easy heat control, since the heat evolution can be spread over two steps. Also the pure titanium crystals obtained by after-reduction are easily removed and leach well. It should be noted that there is not much trouble about the design or materials of construction here as there is with the other continuous processes. Actual results remain to be seen.

Recently Kennecott Copper Corp. and Allied Chemical Co. have announced the building of a $40 million titanium plant using a continuous sodium process. As the detailed process is not disclosed, the advantages of this continuous process are still unknown.

Because of the emphasis on the continuous process, the cost factor of titanium today gives a misleading view of the industry. Little information is available for a cost study. Unfortunately it is the guarded secret of the industry. After years of research backed by experimental production, it is estimated that the labor cost for a 6000-ton titanium plant using the Kroll process is about 8 pct of the total cost. Fifty percent represents the cost of $TiCl_4$, magnesium and other raw materials, while 42 pct is for the other direct costs—amortization, overhead, and profit. In view of the low percentage of labor cost, the high cost of titanium today is not altogether the result of a batch process.

Titanium Slag as Raw Material: It can be seen that the best way to reduce the titanium sponge price is to lower the raw material cost and bring down overhead and fixed charges. To reduce the cost of raw materials it is necessary to find a substitute for rutile and to recycle the magnesium or produce a lower cost sodium. The titanium industry today should concentrate its efforts to make an intermediate product such as high grade titanium slag from ilmenite, which is abundant in the world, to use as the raw material for production of titanium tetrachloride.

The Japanese have been successful in making very high grade slags continuously with less than 5 pct total impurities. To reduce overhead and fixed charge, volume of production must be increased. A plant with an annual production rate of 20,000 tons of sponge, recycling the $MgCl_2$ and using ilmenite as raw material, could produce titanium sponge at about $1.00 per lb. This is not over-optimistic, since the production cost of sponge is already below $2.00 per lb, using rutile at 10¢ per lb and magnesium at 37¢ per lb, without recycling $MgCl_2$, and at a much smaller production volume. It seems that the Kroll process or its sodium modification is here to stay for some time, even if it remains a batch process.

Zirconium

Although zirconium production is similar to that of titanium, production of reactor-grade zirconium has its own problem—the cost of separating hafnium from zirconium. The seriousness of this problem is best illustrated by the following comparisons. Titanium and zirconium are produced in the same manner, with identical chemicals. Considering the greater density and larger atomic weight of zirconium, the zirconium production cost per pound should be less than that of titanium, but it is not. The present high cost of zirconium is mainly caused by hafnium separation and the present low level of zirconium production.

Present methods of separating zirconium and hafnium that are in use or under serious consideration include the Oak Ridge liquid-liquid extraction or modified Fischer-Chalybaeus process, the Ames liquid-liquid extraction, and the double fluoride crystallization. No liquid-liquid extraction process requiring expensive complexing agents, large volume of acids, and expensive corrosion-resistant equipment will ever be cheap.

Ideally, the zirconium compound used for the separation should undergo no chemical change during the process and afterwards could be fed directly into a reduction process. The separation of hafnium and zirconium tetrachlorides by distillation is a distant possibility, but so far no one has succeeded. In fact, the continuous industrial use of the Oak Ridge extraction process for the past six years is eloquent testimony to the difficulty of finding any efficient, economical means of separating hafnium and zirconium. The Commonwealth Scientific and Industrial Research Organization of Australia has patented a process for separating $HfCl_4$ from $ZrCl_4$ which is supposed to cost much less than the liquid-liquid extraction. This process is reported now in pilot plant stage at the Cincinnati Research Laboratory of U. S. Industrial Chemical Co.

Another factor responsible for the present high cost of zirconium is its very low recovery. According to operating data in the USBM zirconium plant, the present economic recovery from different steps to the finished pure zirconium sponge is: raw $ZrCl_4$ to pure zirconium sponge, 50.00 pct; pure ZrO_2 to pure zirconium sponge, 61.73 pct; and pure $ZrCl_4$ to pure zirconium sponge, 61.35 pct.

It is hoped that recovery in the new Wah Chang zirconium plant will be gradually increased by improved design and operation. The percentage of recovery is not a technical problem but an economic one. If economy permits, 90 pct recovery is not impossible.

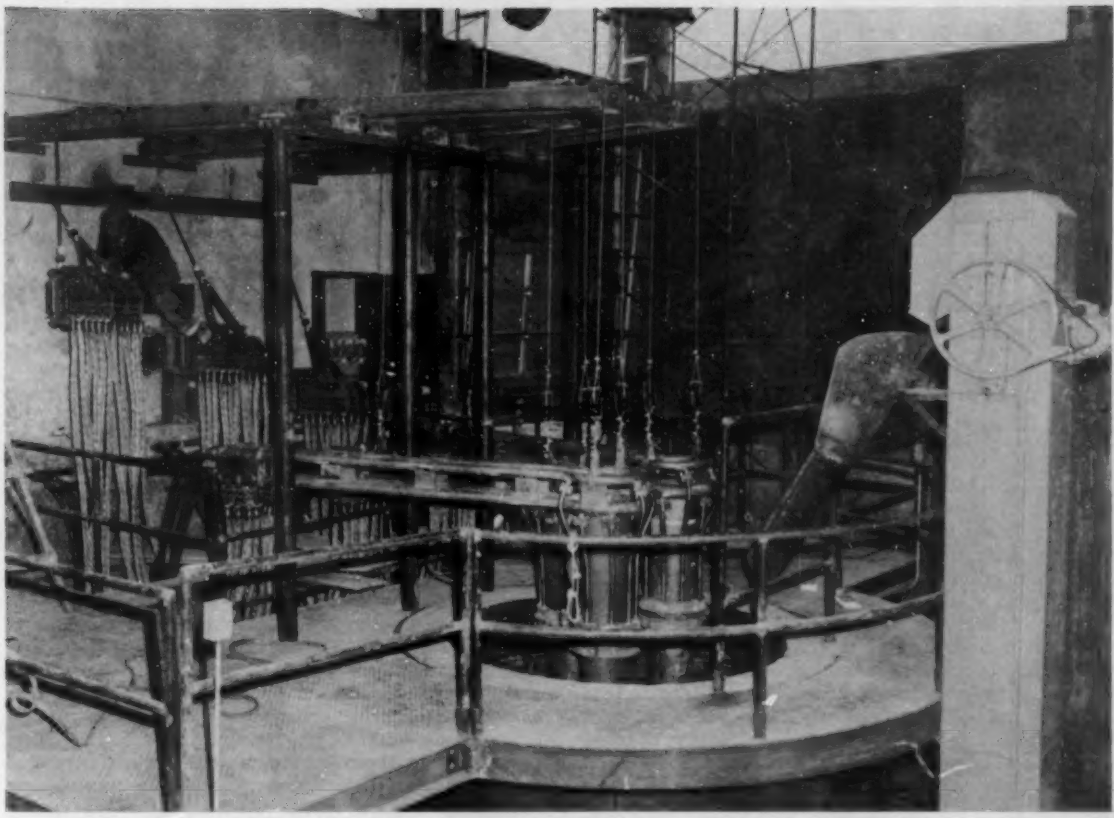
Unlike titanium, which is obtained only as one kind of sponge, zirconium appears in the form of two kinds of sponge—the reactor-grade zirconium and the commercial hafnium-bearing zirconium. The important uses of titanium in aircraft and in the chemical industries are well known. The important use of reactor-grade zirconium is also well known. But the importance of the commercial hafnium-bearing zirconium should not be overlooked.

Commercial zirconium with some hafnium has outstanding corrosion-resisting properties and may prove to be a most useful metal for chemical engineering and other special applications.

According to a Government survey[4] the use of commercial (non-nuclear) zirconium will be tremendously increased by the decrease in price. This survey was made before 1952 when the zirconium ingot price was $25 per lb. The survey shows that if the price were to be reduced to one third, consumption will be increased 12 times, and if the price is reduced to one tenth, demand will be increased 150 times. The survey was limited to a few potential consumers and concerned only a limited application of zirconium. It is believed that if a survey is made today, it will show a much larger potential demand.

Uses Of Zirconium: The most important uses of zirconium are as follows:

1) Chemical Equipment: Although zirconium is considered not quite as good as tantalum against acids such as HCl, H_2SO_4, and aqua regia, especially when it contains carbon, iron, and other impurities,



Smelting furnace installation at new zirconium plant of Wah Chang Corp. at Albany, Ore. Charge elevator is at right

it has better resistance to hot and strong caustic solutions than tantalum. At any rate, it is much cheaper and more plentiful. Zirconium is superior to titanium in resisting oxalic acid solution. In this respect it is a better substitute for glass-lined equipment than titanium.

2) Electric and Electronic Industries: Since zirconium will absorb or form solid solutions with oxygen up to 40 atomic pct and with nitrogen up to 20 atomic pct, it is an excellent nonvolatile getter. The function of a getter in a vacuum tube is to absorb or react with the gases left after the pumped-down and baked tube is sealed off. Zirconium powder will also absorb all the other gases (CO, CO_2, H_2, etc.) except the rare gases (A, He, etc.). Only exceptionally is zirconium sheet or wire being used as a getter.

Because a thin insulating oxide film forms on the surface of zirconium, the metal has possible uses in electrolytic condensers and rectifiers.

3) Neurosurgical Applications: This is a special application of the high corrosion resistance of zirconium. Small quantities of ductile zirconium made by the Kroll process are used for this purpose. Zirconium compares favorably with tantalum in most surgical applications and is definitely superior to silver.

4) Ammunition: In Germany large quantities of fine zirconium powder were used in ammunition primers and in time fuses for bombs, where it was found to have a decisive advantage over other materials because when it is ignited no gas is evolved that could prevent the fuse from burning. Zirconium powder has been used for flashlight powders, flares, fireworks, and detonators.

5) Zirconium Alloys: Zirconium as an alloy accounts for by far the largest part of the consumption in metallic form. Most of the zirconium for metallic purposes is used in steelmaking, but it is fast becoming of great importance in magnesium alloys as a result of increasing utilization of zirconium-magnesium alloys in military aircraft. Zirconium refines the grain of magnesium.

Zirconium production, therefore, will continue to expand. Consumption of reactor-grade zirconium in 1960 may exceed 3000 tons, and consumption of commercial-grade zirconium may be very large if its price can be substantially reduced. This is possible if production capacity is expanded.

In conclusion, it may be said that the Kroll-type reduction remains the preferred method. The major improvement to be made in the titanium and zirconium industries will be in the method of reducing the cost of raw materials, lowering the mechanical maintenance cost, and increasing production volume.

Acknowledgments

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der the program have had to close because the been more than met. From now on industrial devel-

Location of Reactive Metal Resources—the Effect on U.S. Industrial Development

by James Boyd

REACTIVE metals are not only those sufficiently radioactive to be used as fuels, such as uranium and thorium, but all metals that will find application in power reactors. It is required of such metals that they be relatively inert or chemically unreactive, dimensionally stable at high temperatures and pressures, and either very absorbent of radioactivity or transparent to it.

To gain the right perspective concerning these metals it is necessary at this point to explode some erroneous concepts propounded so often they have become accepted as fact. The first of these is that the great industrial nations, especially the U. S., have reached their pre-eminent position chiefly because they possess abundant mineral resources. Some U. S. mineral economists, echoed by the politicians, have taken this position so often that many of their theories and policies are based on the presence of developed mineral resources as a *sine qua non* to the country's greatness. Actually the reverse is true—under a social and political system granting free rein to the initiative and creativeness of its people, many hidden mineral resources that otherwise would have lain fallow have been developed into productive enterprises to the benefit of the national industrial economy. Again, once the proper incentive was furnished, other countries have also been able to establish valuable mineral enterprises in recent years; resources long dormant for lack of a proper economic environment suddenly have become valuable and productive. It is possible to name immediately several nations where such domestic economic developments have had favorable repercussions within the last decade. The absence of productive mines in any country is no indication that workable deposits do not exist within its territory.

The writer would be the last to deny that the fortuitous juxtaposition of coal and iron deposits in the U. S., Great Britain, France, and Germany materially influenced the rapid development of their industrial economies, but a similar association of minerals exists in Russia, and it has taken much longer to take advantage of it under a less stimulating political system. An outstandingly favorable example of this thesis is demonstrated by the dynamic growth of the oil and iron ore industries of Venezuela, stimulated by the enlightened policies of her government. In contrast, the known oil resources of Mexico have languished under government expropriation, and potential resources of Brazil and Argentina remain undeveloped for similar reasons.

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Therefore, before anyone becomes worried about the further industrial development of the U. S. because of the location of presently known resources of required materials, he should be certain that his premise is sound and base his reasoning upon opportunity as well as geology or geography.

To come to grips with questions of reactive metals, consider the nation's uranium position. Only 10 or 12 years ago political leaders, both in the Administration and Congress, were bemoaning the unavailability of uranium within U. S. borders. The U. S. was a *have not* nation dependent on the Belgian Congo for its future and perhaps its life. Fortunately, some in authority were not so defeatist. They reasoned that given the incentive American ingenuity would overcome this situation. A guaranteed market at a worth-while price changed the entire picture in a short ten years. Today the AEC declares that the U. S. is nearly self-sufficient for all foreseeable needs for some years to come. There are still vast areas of this country available for future exploration and, in view of the growing knowledge of uranium geology, the writer predicts that the U. S. will be able to find additional sources of reactive metals as they are needed. In the meantime, the largest known source is the Blind River area of Canada, and the second largest is the byproduct of gold in South Africa, both friendly countries.

Eight years ago, before columbium was thought of as being useful in the reactive metal field, the metal was considered so vital to defense that the Government, thinking in terms of the old *have-not* theory, decided to stockpile all available columbium not immediately required for military jet engines. The metal was withdrawn from use even in applications of considerable military and industrial importance. Yet the projected military requirement demanded several times the columbium available from all known world sources. To continue a stated requirement so far in excess of reality was "stupid" and "ridiculous," according to the statisticians. Wiser and more experienced people insisted that if the military required columbium to produce more efficient weapons a concerted effort should be made to find new and additional sources of the metal.

Following the passage of the Defense Production Act in 1949 a program of guaranteed markets at an established price was instituted. Within four or five years new mines were opened, and a new form of columbium deposit was discovered to occur in such size as to assure the world of all the metal it could absorb in the indefinite future. Within six years the stockpiles were more than filled and the procurement program ended. Many mines that opened un-

der the program have had to close because the markets—previously dried up for lack of supply as a result of the channeling into the stockpile—had turned to substitutes. The new requirements of the atomic age have not yet developed sufficiently to support these mines in renewed operation.

Recent developments pertaining to columbium illustrate economic facts that can be applied to other reactive metals and minerals. The deposits opened to meet the immediate requirements of the crash program were, with one exception, in foreign countries, in this case primarily in Nigeria. The important exception is in Idaho. The new type of mineralized material containing columbium is pyrochlore, which occurs in large deposits in many parts of the world, notably Africa, Brazil, and Canada. So far no important pyrochlore deposits have been found in the U. S., but there is no reason to assume that they do not exist here. As long as the total columbium requirement remains small, Nigerian and other byproduct mines can satisfy the markets for a few years, but they cannot meet the full requirements of the atomic age. Pyrochlore deposits will be required for this purpose and this will involve the solution of difficult metallurgical and economic problems. It is known today that pyrochlore reserves are extensive, and already experimental quantities of columbium metal have been produced from these sources.

Development and mining of these deposits must await the demands of a market that will warrant construction of commercial plants sufficiently economical to process the ores through a complex metallurgical treatment. However, physical metallurgists can proceed with the confidence that when they have learned to use columbium effectively, and have provided the designing engineers with the necessary data, the metal can be made available for their purposes.

A further lesson is to be learned from columbium. Although there are currently no known deposits with U. S. borders, supplies are available in the hands of friendly countries and, therefore, there is no need to worry about self-sufficiency.

It should always be remembered that never in all its history has the U. S. been self-sufficient in all metals. This fact has not inhibited the country's industrial development. Neither has the lack of metal sources inhibited the industrial development of other countries, which in turn have had to depend on the U. S. for materials it produces in abundance. This interdependence between nations acts as a guarantee that shortages in some materials need not restrain industrial development.

Here another question can be anticipated. What happens in case of national emergency, when some supplies are cut off by enemy action? This is the reason for the national stockpiling program, which, if it is continued in its present form, provides the necessary safeguards against such an eventuality. Specifically applied to the reactive metals, stockpiling should be really effective because anticipated tonnages are not large and required Government expenditures for purchasing and storage are by no means prohibitive.

However, except where crash programs are necessary for defense purposes, there is no need for Government incentive and price support programs. Normal laws of supply and demand are still the best guarantee of efficient and effective production. In the case of columbium, the defense requirements have been more than met. From now on industrial developments and market requirements should provide the necessary incentives for the development of the metal.

Even without price incentive, considerable assistance is available from the Government for the asking—a vast amount of metallurgical research is being carried out by and for the military and the AEC. The results of such work are generally available to those who can show a legitimate need for them. The curtain of secrecy surrounding this research is rapidly being raised.

True, while there are tremendous economic possibilities inherent in some of the reactive metals, there are difficult collateral problems to be solved. For example, research on a given metal may be inhibited by lack of immediately available ore, while at the same time exploration and extractive metallurgy may be held back by lack of immediate markets. To resolve such technologic and economic dilemmas, the problem must be approached on several fronts, and it becomes necessary to tackle physical and extractive metallurgical research, marketing, and exploration development methods. There are long gambles to be taken in each step of the program. A company may put its chips on a given mineral deposit only to find that after its money is invested somebody else has discovered another deposit of similar material that is cheaper and easier to mine or process. Still another company may have developed a metallurgical process only to find it has become obsolete through a new method developed by a competitor. A third company may invest in one metal only to find that research in the meantime has proved another metal to be more suitable or superior to the need. This, however, is one of the hazards of a free enterprise system, and also a source of its strength. A free enterprise system guarantees efficient competition by the greatest number and puts a premium on intelligence and ability.

Other metals present problems similar to those of columbium in each phase of production and use. It is impossible to review their individual problems here, but it would be unwise to dismiss the topic without pointing out some specific aspects of the problem that have an important bearing on the future of reactive metals.

In the first place, it must be remembered that as far as can be seen at the moment the problems of these metals are of lesser magnitude than those to be faced by oil, iron, copper, lead, zinc, and aluminum. Tonnage requirements will be smaller and consequently the mines, metallurgical plants, and marketing facilities will be on an entirely different scale. A tungsten, zirconium, or columbium mine, with its metallurgical facilities located in southern California, cannot possibly have an economic impact upon the area similar to that of Kaiser's steel plant near San Bernardino, or the discovery of Signal Hill. The impact of these metals will be felt where they are used in the production of power, but that is not the subject of this article.

However, certain specific problems of individual metals require comment. As regards self-sufficiency, in the foreseeable future this should be guaranteed by large reserves of many of these metals known to exist within the confines of the U. S.—potassium, sodium, vanadium, zirconium, hafnium, uranium, and boron. These metals at the moment present no problems of discovery or troubles of a serious ex-

tractive metallurgical nature not already solved, but some of them will require construction of plants as needs materialize.

There is currently a shortage of molybdenum for other than reactive uses. A large part of the molybdenum supply is dependent on copper production, and the capacity of the largest single mine source at Climax, Colo. Other smaller deposits are known but currently undeveloped. Rhenium occurs only associated with molybdenum in a few of the copper properties. Any substantial long-term use would be limited by the sale of copper, and hence molybdenum, in these particular mines. Its current supply and known uses are small, but if it were required on a large scale it would be necessary to scramble for new sources.

Most of the country's titanium is currently imported, but there are ample sources to meet foreseeable requirements for metal already known and developed within the U. S. and Canada. Whether the ore is supplied from Australia, India, Florida, New York, or Canada at the moment is essentially an economic question.

Thorium is known to exist in the Blind River deposits in Canada in far greater quantities than can be visualized for current use.

Tantalum, with few exceptions, comes as a byproduct of columbium. The known world resources of high-tantalum, low-columbium ores could not support a greatly increased demand; the large new pyrochlore ores are notoriously low in tantalum. The columbium incentive program should also have brought forth tantalum, but it failed to do so. Hence, if tantalum were required in large quantities, those who search for it would require a stable market at a high price to warrant the kind of investigation that led to the discovery and development of potential U. S. supplies of columbium and tungsten. Fortunately, columbium can replace tantalum in many applications, and about half as much columbium, by weight, is required to do the same job tantalum would do.

There are exceptions to every rule. Beryllium may be one of these exceptions. Recurrently, metallurgists are intrigued by the potentialities of this wonder metal. It is light, strong, and resistant to fatigue and corrosion and it has a low nuclear cross section. From time to time great interest is stimulated by the desire to use it in quantity, but each time hopes are dashed by its apparent scarcity in nature. Many geologists have searched longingly and hard, but without success, with the expectation that somehow, somewhere, there may be large concentrations of beryllium minerals in the earth's crust. If a large-scale indispensable (meaning irreplaceable) use were developed, where cost was not a serious factor, perhaps an extensive high-priced campaign could be launched to find it. The writer is not pessimistic about the possibility of finding more beryllium if the proper prospecting tools can be found. The minerals in which beryllium occurs as a constituent are low grade in metal; they are difficult to analyze and difficult to detect (except by spectrograph or microscope—both expensive prospecting tools). For the time being at least, anyone engaged in research or development of the reactive minerals should not count on using beryllium in anything but small quantities. This condition may change, however.

This leads to the *Pandora's box* of elements that may or may not have uses in the reactive metal field—the rare earth metals. As will become apparent, it is difficult to discuss these metals separately. The term *rare earth metals* is used to designate a group of elements originally known as *rare earths*. They were misnamed, because they are in many instances far from rare and although their oxides resemble those of the alkaline earths, the nomenclature is weak. The group consists of more than a dozen elements—there are actually two groups involved that historically have been called *yttria* and *ceria* groups. They are for the most part past the middle of the Periodic Table and carry atomic numbers ranging from 57 to 71.

As a rule, these rare earth metals are found associated with each other, and a single mineral may contain oxides of as many as half a dozen of these strange elements. Monazite sand, the important source of thorium, is also an important source of this series of elements. Monazite sands are widely scattered geographically. Productive deposits are located in India, Brazil, and the Union of South Africa and in Montana, California, the two Carolinas, and Florida (beach sands). There are other monazite sources about which less is known in Australia, Ceylon, Indonesia, Malaya, and Korea; some of them may be important future sources of rare earth metals.

Experimentation and uses of the rare earth metals have been inhibited in the past because of their complex chemistry and the extreme difficulty of separating one element from another or extracting a pure constituent. The metals were formerly extracted through tedious methods of fractional precipitation followed by electrolysis at high temperatures to reduce the compounds to metal, a time-consuming and often expensive procedure. Today, however, new ion exchange techniques are changing and improving methods of extraction and separation.

These elements have suddenly become important in the reactor field. Cerium oxide of high purity permits making a safe glass through which the scientist and technologist can view reactions within the atomic pile. Other extensive uses of rare earth metals appear to be indicated in reactor applications. Their potential is still to be learned.

In 1949, at Mountain Pass in California, there was discovered a very large deposit of bastnaesite, a fluocarbonate of the rare earths. This deposit is extensive and coupled to other domestic sources is capable of supplying all foreseeable raw material requirements for the ceria group of rare earth metals to American industry for years to come. Here is another example of a resource that until recently was on the nation's list of scarce materials—a resource no longer in short supply, because of the search stimulated by a free system.

The technology of the rare earth metals is still in its infancy, but these elements excite the interest of every research metallurgist. They offer a fascinating field for investigation both in respect to their intrinsic properties and possible application.

To summarize, each of the reactive metals taken individually presents few insoluble problems of supply, compared to the steel, lead, copper, and aluminum required in construction of the plants and distribution of the energy and useful byproducts. Almost all of them are available either in the U. S. or from safe nearby sources. Hence, it can be concluded that their location will have nothing but the most beneficial effects on the industrial growth of the U. S., especially in the field of atomic power.

Grinding Practice at Tennessee Copper Co.'s Isabella Mill

by F. M. Lewis and J. E. Goodman

A larger, slow-speed, under-loaded ball mill and hydraulic classifier have almost doubled grinding efficiency at the Isabella mill.

TENNESSEE Copper Co. operates two ore concentrators, the London and Isabella mills near Copperhill, Tenn. In 1948 and 1949 the small ball mills and rake classifiers in the London concentrator were replaced by one large ball mill and one hydraulic classifier. This new ball mill was designed oversize so that it could be operated at slower than normal speed. The proper operating conditions were established and the results published.[1] Later it was found that this mill operated more efficiently with a small ball charge.[2]

While this London grinding practice was being developed, the Isabella grinding circuit was not changed in any way. It remained a conventional two-stage rod mill—ball mill combination, the rod mill in open circuit and the ball mill in closed circuit with a rake classifier. Study of the data indicated that grinding cost could be lowered by converting to the London practice, but not enough would have been saved to warrant the expense of converting. No plan for improving this grinding operation could be developed.

In 1953 this study was reopened when plans were made to increase the Isabella mill output from 1150 to 1500 tpd. At this time the grinding circuit consisted of a 6x12 rod mill followed by a 6x12 ball mill in closed circuit with a 6-ft rake classifier. Another 6x12 ball mill and 6-ft rake classifier would have been sufficient equipment and would have been the simplest and cheapest installation. However, this would have offered no improvement in grinding efficiency or operating cost. If, on the other hand, the grinding operation could be converted to the London practice by installation of one large 10½x9x9 tricone mill and a 10-ft hydroscillator,[*] lower operating costs would justify the additional investment.

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Table I. Comparison of Operating Costs

Grinding Equipment	1 Estimated	2 Estimated	3 Actual
Ball mill size, ft	6x12	10½x9x9	10½x9x9
Motor, hp	200	400	400
Classifier	6-ft rake	10-ft hydroscillator	10-ft hydroscillator
Capital cost, $	95,000.00	160,000.00	155,714.48
Additional investment, $	—	65,000.00	60,714.48
Operating costs, $*			
Liners	0.0263	0.0269	0.0282
Rods and balls	0.1237	0.0935	0.0890
Power @ $0.005 per kw-hr	0.0350	0.0285	0.0270
Total	0.1850	0.1489	0.1442
Savings, cents per ton	—	0.0361	0.0408
Savings, dollars per year**	—	18,400	20,800
Return on additional investment, pct	—	28	34

* Costs of feeders, pumps, operating labor, supervision, and miscellaneous items are not included, since they are constant in either scheme.

** Tons of ore per year, 510,000.

Economics: Table I presents estimates for the two schemes for enlarging the Isabella mill. In the first scheme, column 1, one 6x12 ball mill and one 6-ft rake classifier were to be added. In the second scheme, column 2, the existing small ball mill and rake classifier were to be retired and one large mill and hydroscillator were to be installed. Estimated savings from the difference in operating costs made an attractive return on the additional investment for the large mill and hydroscillator. Actual costs of carrying out this plan are tabulated in column 3b. It will be seen that these costs follow the estimates in column 3a very closely. The return on the additional investment is calculated from the difference in the operating cost in column 1 and the actual operating cost in column 3b. This too come very close to the estimate.

Power and Steel: Power requirements and steel consumption for the rod mills and ball mills, both actual and estimated, are presented in Table II.

The Transactions papers appearing in MINING ENGINEERING during 1957 will subsequently appear in AIME Transactions Volume 208, and may be permanently referenced to that volume.

Table II. Power Requirements and Steel Consumption for Rod and Ball Mills

Equipment and Results	1 Original Plant, Actual	2 First Proposal, Estimated	3a Second Proposal, Estimated	3b New Plant, Actual
Tons per Day	1150	1500	1500	1500
Equipment				
Rod mill	6x12 ft	6x12 ft	6x12 ft	6x12 ft
Ball mill	6x12 ft	6x12 ft(two)	10½x9x9 ft	10½x9x9 ft
Classifier	6 ft FX	6 ft FX(two)	10-ft hydroscillator	10-ft hydroscillator
Pump	5x5 ft	5x5 ft	5x5 ft	5x5 ft
Horsepower				
Rod mill	215.0	215.0	215.0	215.0
Ball mill	225.0	353.0	247.0	226.0
Classifier	6.0	12.0	10.0	7.3
Pump	4.9	7.0	7.0	6.3
Total	450.9	587.0	479.0	454.6
Kilowatt-Hours per Ton	7.02	7.01	5.71	5.42
Steel, Pounds per Ton				
Rod mill liners	0.115	0.088	0.068	0.070
Ball mill liners	0.037	0.047	0.033	0.050
Rods	0.72	0.55	0.55	0.41
Balls	0.77	0.93	0.62	0.63
Product Screen Analysis				
+65	7.9	—	—	7.3
−200	53.0	—	—	53.3

Columns 1 and 3b are from the plant records on 1150 and 1500 tpd, respectively. Columns 2 and 3a are the estimates for the two schemes for enlarging the grinding capacity. In both proposals the 6x12 rod mill was not to be changed in any way. It was predicted that the power input to this mill would not change and that the same pounds of rods and liners per operating day would be required. In column 2, in which another 6x12 ball mill and a 6-ft rake classifier were to be added and operated in parallel with the existing 6x12 ball mill and 6-ft rake classifier, it was presumed that the ball mill grinding efficiency would not change and that the daily increase in pounds of balls and liners would increase in a direct ratio to the additional power input to the ball mills. In column 3a, in which the London grinding practice was to be followed, all credits from the London operation were used in estimating both the power and steel consumption for the ball mill. Actual data in column 3b closely approximate the estimates in column 3a.

Rod Mill: Grinding data on the Isabella 6x12 rod mill are presented in Table III. Columns 1 and 3 are from the plant records on 1150 and 1500 tpd respectively. Column 2, giving the estimated performance for the rod mill on 1500 tpd, predicts that the efficiency of the rod mill will improve on the higher tonnage.*[4] Later a study of the Isabella plant data proved that this prediction was correct, because this rod mill on 1500 tpd was calculated to be 13 pct more efficient than it was on 1150 tpd.

* For a long time the London 6x12 rod mill was handling 1250 tpd with a work index of 6.2. As time went by plant requirements made it necessary to keep increasing the feed rate. Each time the feed rate was increased, grinding efficiency improved. At the present time the work index on this rod mill on 2425 tpd is 4.0. Hence efficiency improved 35 pct as the feed was increased from 1250 to 2425 tpd.

The pounds of rods used per operating day decreased after the tonnage was raised. No credit was taken for this in the estimating because this fact had not been recognized. However, since there was a reduction in the rod wear, the records were studied. They showed that as the grinding efficiency improved there were reductions in rod wear, which can be explained by the widely accepted theory of action in a rod mill.[4,5] The ore at the toe of the rod charge is carried upward between the rods in their upward movement. It is gradually reduced in size as it travels spirally and longitudinally through the rod charge. The highest efficiency must be reached when all the voids between the rods are filled with ore. This reduces the wear on rods, decreasing the rod consumption.

Ball Mill and Classifier Circuit: Table IV presents the Isabella grinding data on 1150 tpd with a 6x12 cylindrical ball mill in closed circuit with a 6-ft rake classifier and on 1500 tpd with a 10½x9x9 tricone mill in closed circuit with a 10-ft hydroscillator. These data show that the present performance with the large, slow-speed, underloaded ball mill and hydroscillator is much better than with the small, high-speed, normally loaded ball mill and rake classifier.

Since 1954, when the Isabella plant was enlarged, grinding practice has been the same at both the London and Isabella plants. Since the change was made at Isabella in one step it is easier to evaluate the economics of this circuit and to show the extent to which the present method of grinding Tennessee Copper Co.'s sulfide ores is more efficient than the old method with small ball mills and classifiers. There is a saving of 30 pct in ball cost and 40 pct in ball mill power over the estimate for two 6 x 12 mills as shown in Table II, column 2. The work index decreases from 11.29 to 6.80. These reductions are somewhat greater than at London, but certain advantages, learned from the London operations, were included in the Isabella circuit. Since the Isabella results were so close to the estimate they prove further that this grinding practice is sound. It is the writers' belief that the rod mill, ball mill, and classifier are components of this efficient grinding circuit. The rod mill controls the size of its product at −8 mesh. Therefore the ball mill has no oversize material and it is possible to use 1-in. grinding balls.[6] With the large slow-speed ball mill the ratio of the mill diameter to ball diameter is favorable

Table III. Rod Mill Grinding

Item	1 Actual	2 Estimated	3 Actual
Tons per day	1150	1500	1500
Horsepower	215	215	215
Kilowatt hours per ton	3.35	2.57	2.57
Feed size, F	15,000	15,000	14,500
Product size, P	390	510	475
Work index	7.89	7.10	6.82

Size, 6x12 ft (inside liners, 5 ft 8 in.); speed, 24.0 rpm; percent critical, 74; rod size, 3 in.; rod load, 45 pct of mill volume.

Table IV. Ball Mill and Classifier Circuit

Item	1	2
Tons per day	1150	1500
Mill size, ft	6x12	10½x9x9
Average diameter inside liners, ft	5.58	9.0
Revolutions per minute	24.0	15.2
Percent critical	74.1	59.5
Ball size	1 in.	1 in.
Ball load, tons	20.5	21.0
Ball load, percent of volume	45.0	20.0
Balls, pounds per ton of ore	0.77	0.66
Horsepower	225	226
Kilowatt-hours per ton of ore	3.50	2.70
Classifier	6-ft rake	10-ft hydroscillator
Percent solids, mill classification	64.0	61.0
	38.0	38.0
Product, +65	7.9	7.3
−200 mesh	53.0	53.3
Feed size, F	390	475
Product size, P	150	137
Work index	11.29	6.8C

for the small ball charge. Also, the hydraulic classifier makes a very satisfactory separation.

When the Isabella ball mill was designed, it was decided to make it a little more oversize than the London ball mill so that further grinding improvements might be realized from a still smaller ball charge. Thus is has been possible to grind the 1500 tons with a ball load occupying only 20 pct of the mill volume instead of the 29 pct at the London mill. Also, the ratio of mill speed to critical speed was reduced further. These two factors—the larger mill with smaller ball charge and the slower speed—probably account for the more favorable power requirements. From the London data, it was estimated that 2.95 kw-hr per ton would be required for the ball mill. Actually only 2.70 kw-hr per ton are required. The shape of the mill was changed, tapering the entire length of the mill instead of tapering only in the cylindrical section. This change probably has no effect on the efficiency. Ball consumption has been slightly higher than the estimate, but this is within permissible limits of error. The big disappointment has been the life of the first set of liners. The wear pattern on these liners was not as expected and the cause of this is believed to be the different shape of the mill. It is expected that this liner life may be improved in future by a change in design.

Conclusions

A larger, slow-speed, under-loaded ball mill and hydraulic classifier are 40 pct more efficient than the small, high-speed, normally loaded ball mill and rake classifier. This corroborates earlier findings at the London plant. The rod mill in this grinding circuit is now 40 pct more efficient because of the higher feed rate.

These results strengthen the belief that for a very efficient ball mill circuit to grind Tennessee Copper Co.'s heavy sulfide ores, the product from the rod mill should be all −8 mesh and 80 pct passing 500μ, and the ball mill should be a large, slow-speed mill—with a small ball charge of 1-in. balls—in closed circuit with a hydraulic classifier.

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Discussion

Tennessee Copper Co.'s Isabella Mill, Copperhill, Tenn.

(Mining Engineering, page 1253, November 1957, AIME Trans., v. 208.)

by J. F. Myers

Much has been written in the past about the non-cataracting ball mill as typified by the installations of the Tennessee Copper Co. at Copperhill and the three units of the Cleveland-Cliffs Iron Co. in its Humboldt and Republic mills.

Because no direct comparisons are available from the Cleveland-Cliffs plants and because the published data of Tennessee Copper Co.'s London mill covered a period of development over several years, it has been difficult for engineers to grasp the full significance of the non-cataracting economics.

Now, for the first time, F. M. Lewis and J. E. Goodman have presented a clear, clean-cut set of figures of the results obtained by conversion from a conventional ball mill to a non-cataracting type of operation, which irrefutably establishes the fact that the slow speed of the non-cataracting ball mill does not lose capacity. This has been the stumbling block in most engineers' minds, as for many years it has been well known that when the ball charge is lowered or the speed slowed down on *conventional mills* the power and capacity drop likewise.

The mill purchased by the authors is designated by the manufacturer as 10½x9x9 ft. By actual measurement, this mill has a mean diameter inside the liners of 9.05 ft and is 9 ft long. In conventional terms this is a 9x9 cylindrical mill.

The question therefore arises as to what size of conventional mill would be required to duplicate the results reported by the authors in Table IV, column 2.

The Bond formula offers a convenient method of evaluation. Proceeding by the Bond method as set forth in the bulletin *How to Determine Crusher and Grinding Mill Size . . . Accurately* we find in Table IV, column 2 that $F=475$ and $P=137$. For our conventional mill size calculation, we obtain the value of Wi by multiplying the Wi value of 11.29 of the conventional 6x12 mill (Table IV, column 1) by 1.294/D[illegible] to correct for the higher efficiency of the 9-ft mill. This turns out to be 10.55. From these data we find that $W=4.17$ kw-hr per ton.

For 1500 tpd we thus find that a motor input of 349 hp is required, and this according to the bulletin calls for a 9x8 mill. Within the permissible range of error in the formula and the recorded data, this may be considered a dead check on the mill size selected by the authors.

In most cases a conversion from the conventional to the non-cataracting type of operation involves reduction in ball size. Obviously, a nice gain in capacity may be expected.

Typical Low Grade Iron Formations of Michigan

Iron formations are classified according to their amenability to concentration.

by Frank J. Tolonen, Nicholas H. Manderfield, and Paul Jasberg

EARLY in the study of the low grade iron formations of Michigan, wide variations in their structure and texture became evident. Because of these variations no simple method of concentration is possible, and those portions of the formations that can be exploited profitably under a given stage of metallurgical progress and existing economic conditions must be searched for carefully.

Both structure and texture of the formations have an important bearing on their amenability to beneficiation. By *structure* is meant the banding planes of easy fracture, the porosity, and the degree of leaching. *Texture*, which includes grain sizes, shapes, and degree of interlocking, determines the amount of grinding necessary to liberate the mineral grains. Structure determines the liberation of portions richer in one mineral. Structure and texture may be termed the *gross features* of the formation.

Earliest surveys of the formations were conducted to outline the parts that could be concentrated at ¼ in. (3 mesh). Operators agreed on this size because anything finer required sintering or other agglomeration processes. At 3 mesh only the structural features, as defined above, would be liberated. With suitable ores concentration was easy, as any of the gravity methods could be used. Sink-and-float gave good results, but with this method only limited portions of the iron formations yielded a desirable product.[1,2] In general, the iron content could be raised to shipping grade, but the silica content remained too high—sometimes 20 pct—instead of 9 or 10 pct.

Grinding did not greatly increase the liberation of silica until 200 mesh or finer was reached. To find the reason for this T. M. Broderick began microscopic examinations of the formations in 1933.[3]

Procedure: The purpose of this discussion is to correlate the appearance of typical portions of the iron formations with their amenability to concentration. As liberation is essential before separation becomes possible, much of the work is based on measuring the liberation achieved by crushing and grinding. Both heavy media and magnetic tube tests were used in this work.

On the basis of general structural features such as banding, degree of alteration, and leaching, a specimen was selected from each part of the iron formations studied. The specimen represents the gross features of the formation and not necessarily the particular formation quantitatively.

One half of the specimen was polished for macrostudy, and the remainder was used for analyses to obtain the grades represented by variations appearing in the macrosection. Specimens for microscopic examination were also prepared for each variation in gross appearance.

For correlation of microstructure with liberation, the previous work by sink-and-float methods was supplemented by magnetizing roasting followed by magnetic separation. The results show the liberation of silica to be very important at the sizes used, because any silica particle with iron minerals occluded would be held in the concentrate. A magnetizing roast changes the crushing and grinding character of the sample. For partly leached soft samples the change is slight, but with harder types and those in which there is a considerable change in crystal structure of the minerals, the increase in liberation of the iron minerals may be 30 pct more than that of unroasted samples at the same crushed size.

Gogebic Range Iron Formations: The Gogebic Iron Range is located in the extreme western and southern parts of Michigan's Upper Peninsula, extending westward into Wisconsin. Samples for this study were obtained from the Ironwood formation, comprising three chief members—the Plymouth, Norrie, and Anvil—with several intermediate slates and thick overlying slates. (The slates are not considered in this discussion because grinding finer than present practice is usually required to liberate the iron minerals.) The predominant iron mineral is hematite, about half of which is hydrated to goethite. Limonite occurs in some of the partly leached areas, and siderite in parts of the formation.

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Fig. 1 shows a macrosection typical of the Plymouth member of the Ironwood formation. The solid light areas in the photograph assay about 60 pct Fe and 14 pct SiO_2. The areas of chert contain 2 to 5 pct Fe. Transitions are gradual, so that areas of intermediate composition make up a large fraction of the total.

The Plymouth member is not uniform. The first 25 ft from the footwall and the last 50 ft to the hanging slate are considerably leaner than the central 100 ft and almost totally lacking in rich bands. Average composition of the member for about 12 miles from the Wisconsin boundary eastward is estimated to be about 13 pct rich bands containing 60 pct Fe, 30 pct rich bands containing about 50 pct Fe, 27 pct mixed bands with about 30 pct Fe, and about 30 pct chert bands with 3 to 5 pct Fe.

Fig. 2 is a micrograph typical of the areas higher in iron content. This shows the intimate interlocking of the silica and the hematite and goethite crystals and indicates the problems in complete liberation of either constituent. The best that can be hoped for is to liberate the richer parts from the cherty portions.

Magnetic tube tests on a roasted sample gave the results shown in Table I, which shows that at 48 mesh grind the iron content would be satisfactory but the silica over 19 pct. At 100 mesh the best that could be hoped for would be 12 pct silica. Further grinding does not reduce silica appreciably. It is then a matter of finer grinding and poorer separation against the cost of eliminating silica in the blast furnace.

The Norrie member of the Ironwood formation has more uniform texture than the Plymouth, and although it is somewhat higher in iron, the possibilities of gravity concentration after crushing to 3 mesh are considerably less.

Fig. 3 shows a macrosection typical of the Norrie member. The portions containing 60 pct Fe are less than half as extensive as in the Plymouth. The 50 pct Fe areas in the two are about the same, but the cherty areas in the Norrie member are considerably higher in iron. Table II lists results of magnetic tube tests on samples after a magnetizing

Table I. Plymouth Member of the Gogebic Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	Iron Recovery, Pct
−10	Concentrate	62.60	48.00	32.42	95.70
	Tailings	37.40	3.60		
−48	Concentrate	51.10	56.20	19.32	92.16
	Tailings	48.90	5.00		
−100	Concentrate	50.29	60.70	12.20	94.02
	Tailings	49.71	3.90		
−200	Concentrate	44.69	61.50	11.80	89.72
	Tailings	55.31	5.70		
−325	Concentrate	48.48	62.73	9.70	94.35
	Tailings	51.52	3.41		
	Head		32.46	52.30	

Table II. Norrie Member of the Gogebic Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	Iron Recovery, Pct
−20	Concentrate	63.7	49.4	28.68	93.7
	Tailings	36.3	5.8		
−100	Concentrate	56.3	55.6	20.58	92.5
	Tailings	43.7	5.8		
−200	Concentrate	54.9	56.4	18.54	92.7
	Tailings	45.1	5.4		
−325	Concentrate	54.1	57.2	17.20	91.6
	Tailings	45.9	6.2		
	Head		34.0	50.00	

Table III. Anvil Member of the Gogebic Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	Iron Recovery, Pct
−10	Concentrate	85.85	36.53	47.62	98.62
	Tailings	14.15	3.10		
−48	Concentrate	69.43	42.65	37.92	98.86
	Tailings	30.57	4.18		
−100	Concentrate	56.95	49.58	29.00	90.83
	Tailings	43.05	6.61		
−200	Concentrate	50.65	53.95	23.00	88.02
	Tailings	49.35	7.53		
−325	Concentrate	50.60	59.30	15.64	94.30
	Tailings	49.40	3.61		
	Head		31.8	53.70	

Table IV. Traders Formation of the Menominee Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	Iron Recovery, Pct
−10	Concentrate	70.35	37.19	46.76	97.87
	Tailings	29.65	1.91		
−100	Concentrate	45.98	50.95	28.20	89.63
	Tailings	54.02	5.02		
−200	Concentrate	43.69	52.71	25.44	89.21
	Tailings	56.31	5.42		
−325	Concentrate	40.81	55.12	22.78	85.74
	Tailings	59.19	6.32		
	Head		25.90	61.92	

Table V. Crystal Falls Carbonate Formation of the Menominee Range

Band*	Fe, Pct	SiO_2, Pct	P, Pct	S, Pct	Mn, Pct
1	30.8	19.84	0.70	0.166	4.24
2	12.8	69.58	0.18	1.04	0.96
3	28.6	21.44	1.46	0.491	2.96
4	25.8	40.82	0.24	1.34	2.12
5	17.8	53.82	1.90	0.206	1.48
Average	25.4	42.72	0.27	0.485	1.70

* Refer to Fig. 6.

Table VI. Crystal Falls Carbonate Formation of the Menominee Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	S, Pct	Mn, Pct	Iron Recovery, Pct
−20	Concentrate	56.96	40.5	29.30	0.60	3.90	84.00
	Tailings	43.04	9.46				
−65	Concentrate	38.4	47.29	18.66	0.749	4.62	66.71
	Tailings	61.6	14.70				
−100	Concentrate	34.6	49.34	15.06	0.633	5.06	62.84
	Tailings	65.4	15.42				
−200	Concentrate	32.1	53.4	9.90	0.834	5.08	60.30
	Tailings	67.9	16.6				
	Head		28.39	47.75			

Table VII. Republic Area of the Marquette Range

Mesh	Product	Wt, Pct	Fe, Pct	SiO_2, Pct	Iron Recovery, Pct
−10	Concentrate	82.49	51.95	26.3	99.12
	Tailings	17.51	2.18		
−48	Concentrate	71.92	56.80	16.66	98.18
	Tailings	28.08	2.79		
−65	Concentrate	68.05	59.80	15.40	97.46
	Tailings	31.95	3.34		
−100	Concentrate	62.90	65.26	8.40	96.34
	Tailings	37.10	4.20		
	Head		43.40	35.9	

Macrosections and Microsections of Specimens From Three Michigan Iron Ranges

Structure and texture of these polished sections of samples of iron formations are correlated with the liberation achieved by crushing and grinding. This correlation may be used as a basis for selecting portions of the iron formations for concentration studies and also for estimating the amounts and the quality of ore that can be utilized.

THE GOGEBIC IRON RANGE

Fig. 1—Macrosection typical of Plymouth member of the Ironwood formation.

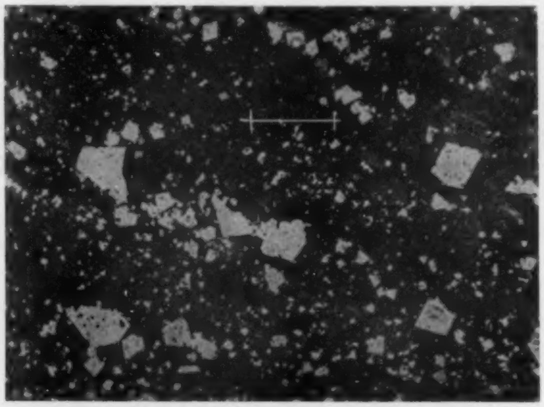

Fig. 2—Micrograph of Plymouth member. White areas are geothite pseudomorphous after magnetite. Scale 100 mesh.

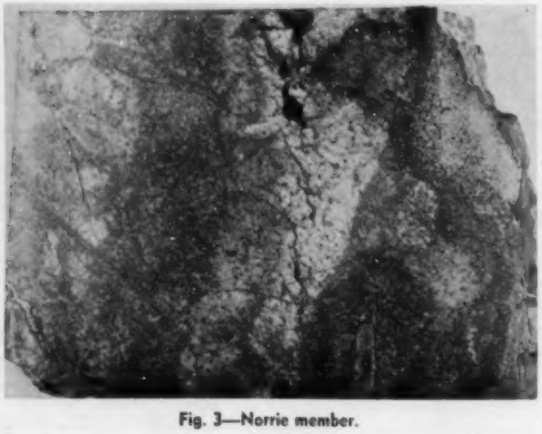

Fig. 3—Norrie member.

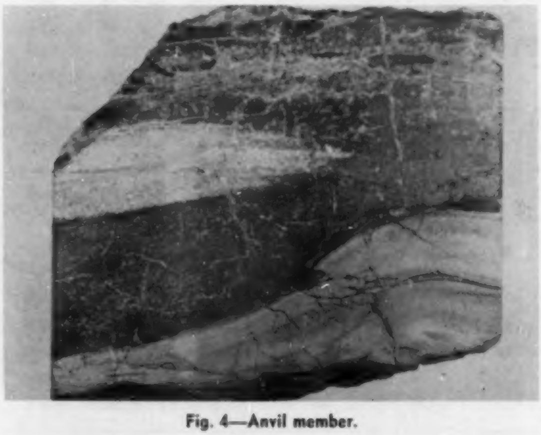

Fig. 4—Anvil member.

THE MENOMINEE IRON RANGE

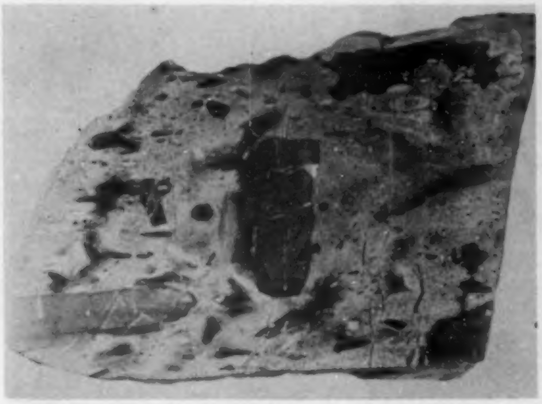

Fig. 5—Macrosection of sample from the Traders formation.

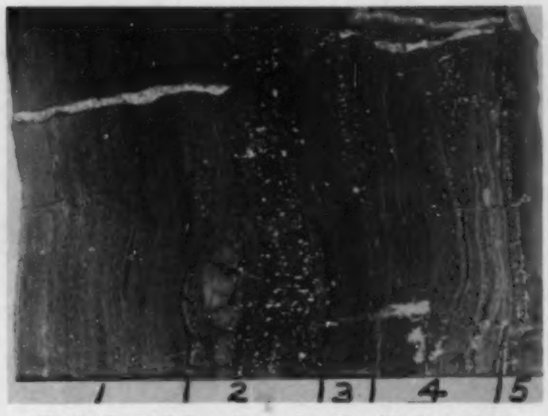

Fig. 6—Crystal Falls carbonate formation. Numbers refer to text and Table V.

THE MARQUETTE IRON RANGE

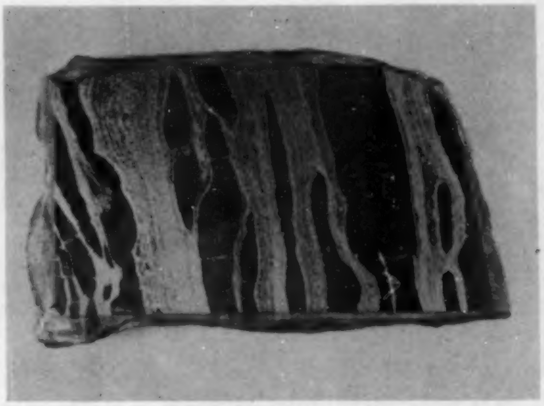

Fig. 7—Republic area.

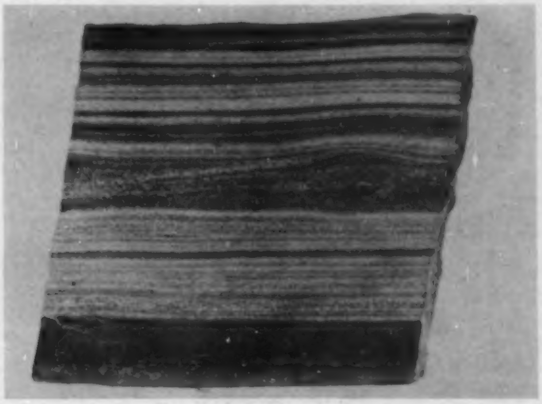

Fig. 8—Republic area.

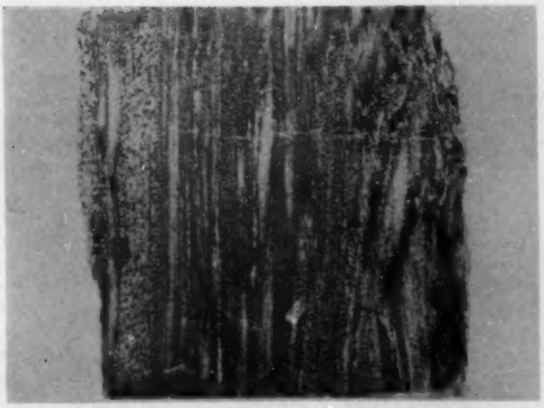

Fig. 9—Sample from magnetic iron formation near Humboldt.

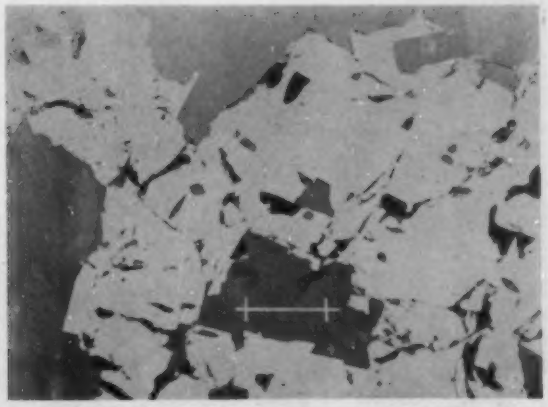

Fig. 10—Micrograph of Humboldt magnetite (white). Scale 100 mesh.

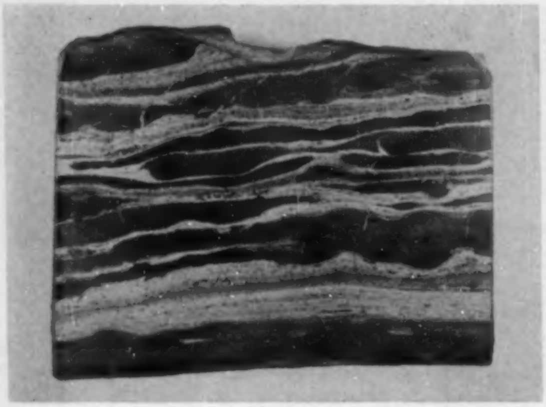

Fig. 11—Macrosection of metamorphosed iron formation south of Negaunee.

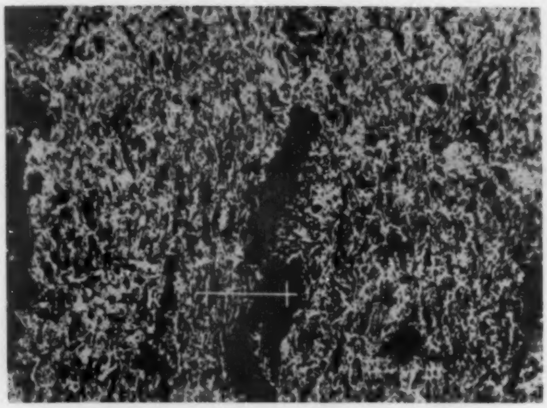

Fig. 12—Micrograph of richer bands of Negaunee formation. Note intimate interlocking of hematite (white) and silica. Scale 100 mesh.

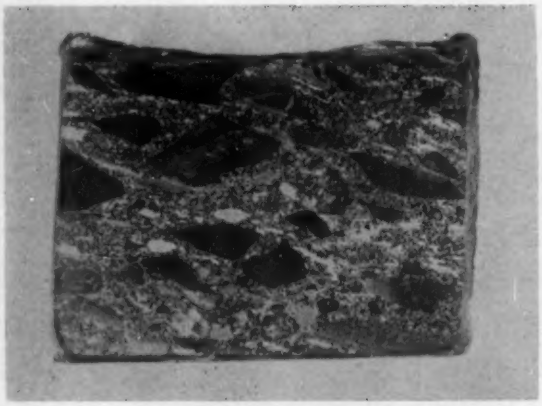

Fig. 13—Central area.

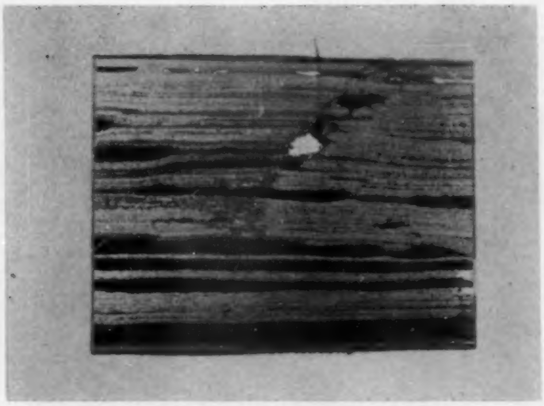

Fig. 14—Cooper Lake district.

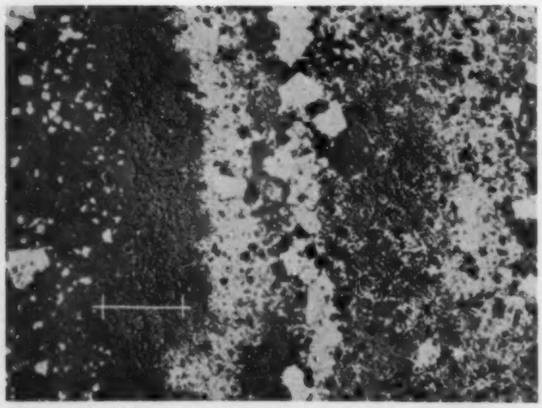

Fig. 15—Micrograph of Cooper Lake district specimen. Richer bands (white) assay about 55 pct Fe and 15 pct SiO_2. Scale 100 mesh.

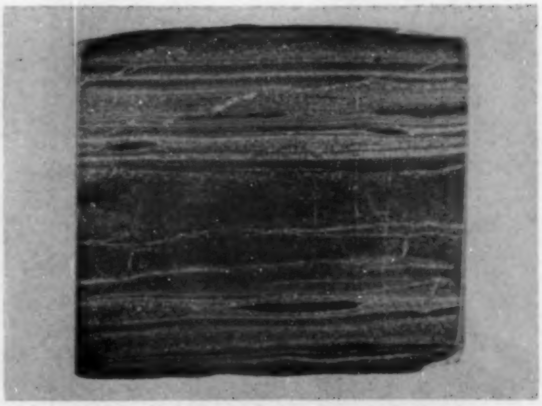

Fig. 16—Macrosection of formation at extreme western end of Marquette Range. Even at 325 mesh the concentrate would contain 20 pct SiO_2 or more.

roast. It will be noted that about 20 pct of the silica is finely dispersed with the iron minerals and that grinding to 325 mesh will not appreciably liberate the fine iron minerals.

Fig. 4 shows a macrosection typical of the Anvil member of the Ironwood formation. Although the iron is higher on the average than in either the Plymouth or the Norrie, the 60 pct Fe areas are not extensive. The lighter area assays about 55 pct Fe and 17 pct SiO_2. The darker areas contain about 22 pct Fe and 65 pct SiO_2. The cherty areas contain 7 pct Fe and 88 pct SiO_2. Results of the magnetic tube test on samples subjected to a magnetizing roast are given in Table III. The micrographs for both the Norrie and Anvil (not shown) are similar to those for the Plymouth member shown in Fig. 2. Table III reveals that even after grinding to 325 mesh a concentrate with only 10 pct silica cannot be obtained. The fine grained character of the minerals is apparent in the micrograph of the texturally similar sample of the Plymouth member shown in Fig. 2.

Menominee Range Iron Formations: The Menominee Iron Range, about 75 miles east of the Gogebic, is in the southwestern part of Michigan's Upper Peninsula except for a small central portion in Wisconsin. The iron formations of this range are more complex than those of the Gogebic. Some portions are somewhat similar to the Plymouth in structure, but folding and other geologic changes have altered the formations to such an extent that samples show wide differences. Sulfur and phosphorus offer additional problems in some locations.

Fig. 5 shows a macrosection of a sample from the Traders formation. The richer portions assay about 27 pct Fe and 60 pct SiO_2. The chert contains about 7.4 pct Fe and 86 pct SiO_2. Table IV, which presents the results of magnetic tube tests on samples after a magnetizing roast, reveals that after grinding to 325 mesh the iron is still not sufficiently liberated to make a concentrate with less than 10 pct silica.

Fig. 6 shows a macrosection from the Carbonate formation at Crystal Falls. The bands from left to right assay as shown in Table V. Table VI shows the results of magnetic tube tests on samples after a magnetizing roast. In these samples the silica is freed by the change in crystalline structure when iron carbonate is converted to magnetite by the reduction roast. The texture is too fine for liberation by grinding alone, resulting in poor iron recovery.

Marquette Range Iron Formations: This range is in the south central portion of the Upper Peninsula. A variety of iron minerals has resulted from the metamorphic changes undergone by the formations early in their geologic history. There are areas of carbonates, earthy hematites, specular hematites, and magnetites. Only a few examples are presented here.

Figs. 7 and 8 show macrosections from the Republic area. The iron, which is present as specularite in the rich bands, varies from 63 down to 45 pct. Amounts of silica vary from less than 10 pct to as high as 30 pct. The chert bands contain 5 to 20 pct Fe. In Table VII, showing results of magnetic tube tests on roasted samples from the leaner portions of the Republic area, it will be noted that a satisfactory silica separation can be achieved at 100 mesh. For some samples from this area a grind of 48 mesh was sufficient.

Fig. 9 shows a macrosection of the magnetic iron formation near Humboldt. There is little difference in the composition of the larger structural units, but as can be seen from Fig. 10, the grain size is fairly large. Liberation is possible at 100 mesh or even coarser sizes.

Fig. 11 shows a macrosection of metamorphosed iron formation south of Negaunee. The rich bands contain 58 pct Fe and 15 pct SiO_2 and the red chert contains 13 pct Fe and 78 pct SiO_2. Fig. 12 is a micrograph of the rich bands. The extremely fine grained and intimate intermixing of the hematite and silica will not permit rejection of silica below 12 pct even at 325 mesh.

In Fig. 13, showing a macrosection typical of the Central area, the iron minerals are fairly large and clustered. Fig. 14 shows a macrosection of another sample of this same type. The richer parts are fairly free of silica so that a 150 mesh grind will produce a satisfactory concentrate. The micrograph in Fig. 15 is representative of the leaner bands. Here the clustered areas can be liberated somewhat from the chert on fine grinding, but the total gain would be small.

Fig. 16 shows a macrosection of the iron formation at the extreme western end of the Marquette Range. The iron-rich bands are thin and the grains small, so that even at 325 mesh the concentrate would contain 20 pct SiO_2 or more.

Conclusions

This study does not attempt to present all the types of iron formations occurring in Michigan.

The macrosections show the gross features. Discrete banding and other larger sized units, whether ore or gangue, will be liberated at fairly coarse crushing sizes. If any appreciable amount of the liberated particles is pure enough to constitute an acceptable concentrate, separation at this size will be warranted.

Part of the ore will require fine grinding, as shown by the micrographs. Grain size is a close measure of the liberation size in ores containing specularite and in ores given a reduction roast. This may not be true of ores with intimate interlacing of minerals.

This study points to the possibility of classifying formations according to amenability to concentration. Such a classification would be of value in the investigation and development of Michigan iron formations. Research studies guided in this manner can emphasize iron formations that have economic possibilities by known mineral dressing processes.

Some of the formations studied will not yield a concentrate with less than 10 pct SiO_2. Concentrates with 12 pct SiO_2 or more might be usable without significantly increasing the cost of steel.

Acknowledgments

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Foundations for Mill Construction on Clay and Permafrost

by E. H. Bronson

PROPERTY of Malartic Gold Fields Ltd. is situated in the great clay belt in the northern part of the Province of Quebec. This belt represents the floor of the glacial lake Barlow-Ojibway. The clay blanket has a gently rolling, almost flat surface, with here and there projecting knobs and ridges that outline the large irregularities of the surface on which the clay was deposited. At irregular intervals glacial eskers dominate the landscape. The ore-bearing country rock is covered by strata of clay, sand, and silt to a depth varying to 40 ft. There are serious structural problems when it is necessary to place loads of unequal intensities on this surface to support buildings and machinery for a modern mining plant.

Earlier mining companies and their engineers paid little attention to the science of soil mechanics, partly because they believed it unnecessary and partly because they knew little of the subject. The results are evident in some of the tottering structures in older camps. Careful analysis of soil problems is well worth-while, since cost of foundations may vary from 20 to 50 pct of the final cost of a structure. Low operating and maintenance costs can be achieved only in this way.

If it is definitely established that a plant will be in operation for only a few months, this limited time factor will probably influence the design of the foundation, and rightly so. If sensitive and complicated equipment is to be mounted on these foundations and the plant is to operate for several years, there should be a thorough study of foundations and a very careful design. A familiar problem is presented by the difficulty of operating a permanent plant originally designed for a few months' work. The engineer must beware of these hazards and disassociate himself from them if he cannot prevail on the promoter to spend the proper amount for a thorough foundation study. Laws of certain provinces and states hold the engineer equally responsible with the contractor for any damage that may be caused to building through inadequate study—ignorance of the facts is no excuse in the eyes of the law.

Types of Soil: The engineer should be familiar with such terms as *silt*, *clay*, *peat*, and *varved clay*, as well as *permafrost*, especially if he is to work in the far northern reaches of the country. He should also be familiar with soil attributes such as porosity, texture, consistency, permeability, compressibility, consolidation, and shearing resistance.

The design of any foundation requires an accurate knowledge of the physical properties and location of the soils involved. Older textbooks on the subject outline various empirical methods to determine the carrying power of soil. Tables are given in reference books. The modern engineer should be wary of these modes of thinking. He should analyze his problem carefully, calculate to what depth of soil the loads may be transmitted, and then check the bearing value of all soils to that or greater depths. If the strata are water-carrying, he must determine the possibility of this water being accidentally re-

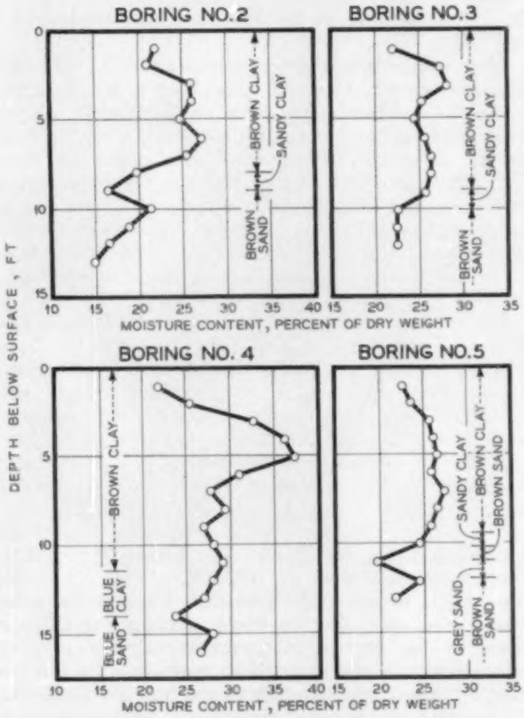

Fig. 1—The number and spacing of auger holes will depend on the size of the site, the relative importance and weight of machinery to be installed, and subsequent information obtained as these boreholes are being sunk.

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moved, and what the effect would be on the bearing value.

The first approach to soil study is a knowledge of the structural and historical geology of the area. The Geological Survey of the various states and provinces should be consulted. A study of the formation of the soils is very valuable. Groud water depths also are frequently available either from geological surveys or data on local wells.

Testing by Auger: Assuming that the proposed building site is above water, the simplest way to determine the subsurface structure is to bore a series of holes with a hand auger. These can be taken to 30-ft depth without difficulty. Neighboring mines may have brought stopes or raises to the surface or excavated deep trenches. These exposures should be carefully studied to note whether or not subsidence has occurred, and why.

The number and spacing of auger holes will depend on the size of the site, the relative importance and weight of the machinery to be installed, and subsequent information obtained as these boreholes are being sunk. It is possible for the intelligent observer to determine during the drilling the types of soil that are being exposed. By obtaining the actual moisture content of samples, he can determine the relative variation of natural water content from one drillhole to the next. After this information is plotted on graph paper, it is possible to obtain a picture of underground conditions by superimposing one graph upon another. (See Fig. 1.)

There is considerable variation in the moisture contents at which different clays pass from liquid to plastic and then to solid state. Moisture content at these transition points can be used for identification of the type of clay in the sample. Knowledge of the type of clay gives a better understanding of its peculiarities for supporting foundation loads. The method commonly used to determine the limits of consistency is known as the Atterberg method, and the limits themselves are termed the Atterberg limits.

So it is that the natural moisture content is of interest and some use, but fully significant only when compared with the moisture content at which the soil in question changes from plastic to liquid. This point is called the *lower liquid limit*. A corresponding consistency limit is the moisture content at which the soil goes from a plastic state into a semi-solid. This is called the *lower plastic limit*. The difference between the two, called the *plasticity index*, is a useful guide to soil properties in general. For example, true clays have a relatively high value for the plasticity index, whereas the highest value obtained for the samples from the particular property at which this work was being done was 24 pct. This was a further indication that the material was really a silt, or rock flour.

Laboratory Testing of Soil Samples: At the property of Malartic Gold Fields Ltd. 15 samples were tested for these consistency limits. Results are summarized in Fig. 2. With geologically similar soils, the points obtained should lie in a straight line. In all cases the lower liquid limit is close to the natural moisture content, and in some cases below this value.

The soil property most important to foundations design is shear strength. Two special undisturbed samples of the silt from the building sites were obtained in zinc dust cans by carefully cutting round the soil as the cans were sunk over the sample sites. The cans were coated with liquid paraffin before

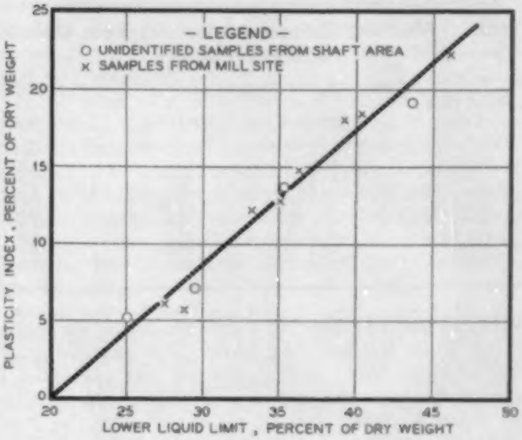

Fig. 2—Summary of Atterberg test results, Malartic Gold Fields Ltd.

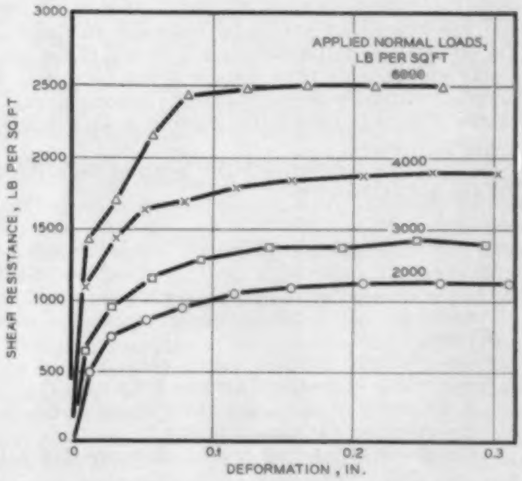

Fig. 3—Experimental results of shear tests on first sample (from shaft area).

being shipped to the testing laboratory. On their arrival, the specimens were placed in the shear machine for test under different normal loads. To simulate actual conditions under the structures that are to be erected, each specimen was left under the normal load applied until no further consolidation of the specimen took place. This consolidation is equivalent to the settlement that takes place under a loaded structure founded on clay. Experimental results are shown in Fig. 3. These give maximum values for the shear resistance under each normal load and are, in turn, summarized in Fig. 4, which also shows the angle of internal friction. From these the safe bearing of the soil can be determined. No attempt has been made to take the highest possible interpretation of test results, but only to obtain a figure that can be used with confidence.

The moisture content of the various samples was taken before and after loading. The chart, Fig. 4, reveals that there is no appreciable change in moisture content during the loading. This is contrary to most findings, wherein the difference in moisture content would vary with the normal load. The practical significance of this information is that

Table I. Moisture Content of Samples from Malartic Gold Fields Ltd.

Normal Load, Psf	Before Test	After Test	Difference
2,000	36.1	34.7	−1.4
3,000	36.4	35.9	−0.5
6,000	32.7	32.9	+0.2
8,000	37.9	33.2	−4.7
4,000	33.6	31.0	−2.6
6,000	30.0	28.3	−1.7
8,000	28.8	28.6	−0.2
9,000	31.0	27.7	−3.3

with careful engineering there should be no settlement under the building loads. The explanation of the unusual result is that the silt was subjected in glacial times to the pressure of superincumbent ice. This consolidated to such an extent that the loads now indicated are smaller than those to which it was previously subjected.

Foundations in General: Following research, it was decided that suitable foundations on spread mats could be developed for the various structures and machines that would be normally included in the surface and mill installation. Details of the necessary calculations need not be given here, but in summary it may be recorded that the bearing strength of the clay was calculated according to Prandtl's modified formula.

Calculations for the ultimate bearing capacity of the silt are as follows:

$$q = \left[c \cot \phi + yb \tan (45° \frac{\phi}{2}) \right] \times \left[\tan^2 (45° \frac{\phi}{2}) \, e \, \pi \tan \phi - 1 \right]$$

Where:

q = ultimate bearing value, psf
$2b$ = width of footing (assume 4 ft)
y = density of soil (assume 90 lb per cu ft)
c = cohesion (assume 200 psf)
ϕ = angle of internal friction (assume 220 psf)

Hence: $q = 11{,}540$ psf.

Using a safety factor of 4 obtained an allowable bearing pressure of 3000 lb per sq ft. This was a maximum figure; the average figure being used was 2500 lb per sq ft.

It was further recommended that this loading be kept as nearly uniform as possible. It was also essential for stability that the center of gravity of the load coincide with the center of pressure from the foundation or footing. This especially applied to foundations for ball mills and their motors. All footings were kept as close to the natural ground surface as possible to take advantage of the maximum strength of the silt underlying the foundations.

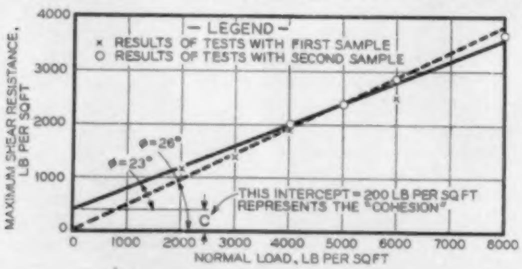

Fig. 4—Summary of shear test results.

As a matter of interest, certain other precautions were taken:

1) After the muskeg had been removed from the building site, the uncovered silt was protected with a few inches of sand to prevent its drying.

2) Because of the instability of the silt, it was stressed that no excavation should be left open during the construction program. If confined, silt will behave normally, but if seriously disturbed it will run like a thick liquid. Deep trenches must not be left unsupported no matter how stable they appear to be. Exposed faces of the silt should be covered with tarpaulins to prevent their drying, or eroding during a heavy rain.

3) Under no circumstances must the underlying sand be allowed to move. Shafts and raises must be carefully driven so that neither the sand nor its contained moisture will be disturbed.

Severe loads such as those for the fine ore bins and head frames must be carried either on concrete caissons or piling.

The first possibility considered was to sink a caisson to bedrock, later filling it with concrete. Doing this through the quicksand and water would be extremely expensive, and getting rid of this water by pumping would disturb the soil. Otherwise, it would be necessary for the men to work under compressed air, which is also expensive.

The next alternative was to drive end-bearing piles, but there was no local timber of sufficient strength and quality. It would have been simple enough to use steel piles, but at the time of construction they were extremely difficult to obtain. Precast concrete piles would have necessitated accurate borings to the rock at the site of each pile to determine the exact depth. So it was decided to use cast-in-place piles, made by an outside contractor who specialized in this type of work. A contract was awarded to the Raymond Concrete Pile Co. of Montreal.

Since all the piles acted as end-bearing piles, in other words, as columns supported at their lower ends on bed rock, the driving records were not as important as if they had been friction-bearing piles. Some records are plotted in Figs. 5 and 6. It will be seen that for three of the piles resistance increased noticeably with depths, as would be expected. But in the case of the fourth pile the increase is not nearly as marked. A recent borehole to check this pile showed that the ground in that vicinity was unusually wet, the moisture content being over 40 pct. It is believed that the large quantity of water made it easy for the driving operation to puddle the soil. This did not invalidate the pile as a bearing unit, but it did indicate the need for caution in using the natural ground in that vicinity for carrying bearing loads direct.

Subsequent construction work was satisfactory, and the plant has been in operation about ten years without difficulties caused by settling foundations.

Soil Exploration by Sampling Spoon: A different type of problem was presented at Bevcourt, several miles east of Malartic, when it was necessary to determine the bearing value of soil overlain by a shallow swamp. Hand auger holes were not possible, as water poured into any opening so produced.

Engineers had recourse to a sampling spoon, a hollow steel tube mounted on the end of drill rods. This is forced or driven through a casing into the soil. Rods and mechanism are supported on a tripod.

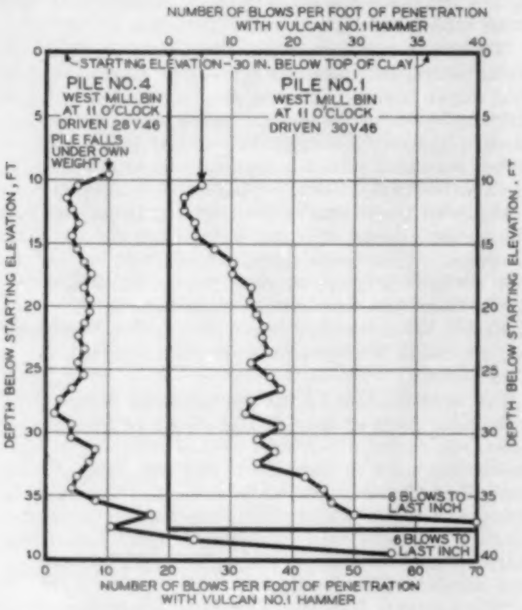

Fig. 5—Driving records for Raymond step tapered piles.

Relative cohesion of the soil is determined by the *standard penetration test.* A sampling spoon is driven 6 in. into the soil to be tested. A standard weight of 140 lb falling a distance of 30 in. is used to drive it 12 in. further. The relative number of blows required to force this weight through this distance gives an index of the cohesion, and hence the bearing power of the soil.

Soil samples are obtained by another type of sampling spoon, a steel pipe about 1½ in. diam and 1 or 2 ft long, split lengthwise. The two halves are held together at the ends by short pieces of threaded pipe. One coupling fastens the spoon to the rods; the other acts as a cutting edge.

The usual practice is to force the split spoon into the soil under pressure. The sample so recovered is examined by the drill foreman and recorded, and a portion is retained in a screw top jar for further laboratory study.

If samples are required for laboratory shear tests, the split spoon is equipped with a thin-walled cylindrical liner. The entire liner, with its contents, is removed from the spoon and shipped intact to the testing laboratory after the ends have been sealed with paraffin. It is essential, especially in clay soils, that the sample be undisturbed; therefore the sample spoon must be pushed into the soil with a hydraulic jack, not driven.

In certain types of soil there may be complications. Sand presents problems requiring a special spoon. An experienced contractor should be equipped for all types of soils normally encountered in the district in which he is working.

When soil borings were taken at the Bevcourt job they showed that in spite of the forbidding surface, there was good foundation soil under the entire area. The swamp was drained with comparatively shallow, wide ditches and the overburden of muskeg removed with a bulldozer. Heavy foundations were carried on footings sunk to the coarse sand. The fine silt inside the walls was stabilized with waste rock and compacted with construction trucks. Finally, reinforced concrete mats and floors were placed for the lighter loads. No detrimental settling has occurred.

If the base of a foundation is located below the water table, it is advisable to transform at least one drillhole into an observation well to check the movement of the water table during construction. If concrete is to be placed below the water table, water samples should be taken from several drillholes to determine the possible presence of detrimental chemical constituents in sufficient quantity to attack the concrete.

Vibration: When machinery with regularly reciprocating parts is based on clay, even though the foundations may be of massive construction, there may be a resonant vibration of serious proportions. This is especially true with crushing plants and air compressors. This vibration must be taken into consideration when building material is chosen. Concrete block walls, for example, will not be satisfactory under these conditions.

Several methods have been suggested for dampening vibration. A cone crusher may be mounted on rubber pads with the hold-down bolts left moderately loose. Jaw crushers of certain sizes may be mounted on timber. Both rubber and timber absorb some of the vibration between the machine and the concrete foundation on which it is mounted.

A further method is to dampen the vibrations by breaking the resonance. When three air compressors, all of different speeds, were mounted on one concrete mat each wave of vibration was overcome by those from its neighbor, and therefore the total effect was very limited. Care must be taken that each vibration does not increase from the other and thus accentuate rather than diminish the effect.

Another instance of diminishing vibration is the use of crushers of different speeds. One jaw crusher is mounted on a concrete mat that was floated on clay. The original vibration was extremely heavy, but when the secondary crusher having an entirely different speed was placed in operation overall vibration was eliminated.

Permafrost: As activity in the mining industry trends steadily northward, a new type of foundation problem is encountered, a condition known as *permafrost.*

One half the area of Canada, half the USSR, and much of Alaska—approximately one fifth of the land area of the world—is constantly frozen near the surface. This includes all of the North West Territories of Canada, part of northern Ontario, and a large section of the Province of Quebec. Some of this vast area consists of exposures of solid rock, the properties of which are not significantly changed by freezing. But when water-bearing soils of various consistencies form the surface of the ground, their characteristics can be markedly affected by changes of temperature above or below freezing.

The presence of permafrost in northern Canada was noted by Alexander Mackenzie during his explorations in the Arctic in 1789. Underground mining by Eldorado in 1932 at Great Slave Lake encountered frozen rock at depth. But it was not until the last few years, with the building of the Alaska highway and various airports, that the subject became of outside interest. Conventional construction methods for roads and buildings, especially buildings with warm basements, resulted in a sad story. It has been necessary to develop a new ap-

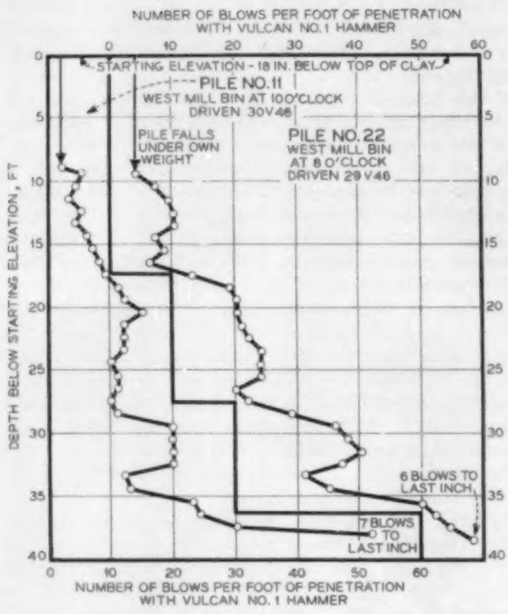

Fig. 6—Driving records for Raymond step tapered piles.

proach as the basic characteristics of permafrost become better known.

Research work has been started by the U. S. Army Corps of Engineers, various research bureaus in the USSR, and the Division of Building Research of the National Research Council in Ottawa, Canada. This last group has provided much of the information that follows.

The ground in permafrost areas consists of an upper or active layer that freezes and thaws seasonally, and a permafrost zone that remains continuously frozen.

Depth of the active layer depends on vegetation cover, type of soil, water content, topography, and climate. In areas undisturbed by construction, a thermal equilibrium is established. The insulating power of the vegetation cover and the active layer preserves the permanently frozen ground. This equilibrium is very sensitive to changes, and any alteration causes corresponding variation in the depth of the active layer. For example, the moss covering the surface acts as a natural insulation to preserve the ground underneath in a frozen condition. But if the moss is removed, warm rays of the summer sun change this hard frozen ground to a fluid material having practically no bearing value. This occurred many times during construction of the Alaska highway.

Depth of permafrost varies considerably over the northern regions. On the shore of the Arctic Ocean it may be 1000 ft thick; at Hay River, near the northern border of Saskatchewan, it is about 5 ft. No definite unbroken line of demarcation can be established between completely frozen ground and completely thawed ground. Small isolated areas of permafrost occur south of the zone normally considered to be clear, owing to the high insulating value of exceedingly thick surface peat deposits in some districts. It is also possible to find areas of unfrozen ground in what is considered a permafrost area. This may be due to the presence of gravel, which does not freeze as readily as clays or silts with high moisture content.

There are two simple, practical field methods for determining the depth of the active layer—rodding and auger boring. The rodding method consists in driving ¼-in. or ½-in. sharpened steel rod with a sledge hammer through the active layer until it meets refusal. The rod is then turned with a wrench. If it turns freely, it has probably been stopped by a rock, but if the rod has a back-spring, it may be that the tip has penetrated the permafrost a very short distance. Also, the ringing sound given off by the rod when it is dropped onto the rock is quite different from the drill *clunk* when the rod hits permafrost. This method is not effective where there are scattered boulders or where the active layer is very thick.

For investigation of the permanently frozen soils a modified form of diamond drilling has been developed. A carballoy instead of the commercial diamond was used in frozen silt and fine sand. Close control of the wash water is essential. Too large a volume of water washes away the core, whereas too small a quantity will not carry the drill cuttings. Speed is naturally important in examination of core and embedded ice crystals.

The unstable properties of frozen soil have two manifestations—the detrimental action of frost and the loss of strength in permafrost when it is thawed by construction methods. These two destructive forces can occur individually or together. Both actions must be considered in foundation design.

During the frozen period the action of frost lifts piles or surface foundations, which settle during the melting period. In sandy soils this movement may be small. A very destructive force may be encountered in clays or silts; the high may cause volume changes from 40 to 200 pct.

Loss of strength in permafrost, when it consists of frozen silt or clay, is of serious concern. If testing has determined that this permafrost is an island of limited area, it should be removed by stripping the overburden and exposing it to the warm rays of the sun, melting with high pressure steam, or blasting and scraping.

If the permafrost is continuous over a large area, a temporary building or a structure for light loads can be floated on the stabilized soil. The natural surface covering of the soil must not be disturbed, but rather augmented by several feet of sand or other insulation to protect the soil from destructive warmth from the building. Timber pads or mud sills on this augmented insulation will carry the structure. Even frame dwellings can be successfully maintained in this manner, especially where no basement is attempted and the floors are heavily insulated with sand or moss underneath.

Permanent buildings or those containing heavy concentrated loads require the transfer of these loads to the solid underlying permafrost by end-bearing piles or concrete foundations. Posts are useless because of frost heaving. Wood piles are generally used because they are locally available and because wood is a poor conductor of heat. A high-pressure steam jet is pushed into the frozen ground, settling downward as the soil thaws. As soon as it reaches the desired depth it is withdrawn and replaced by a wooden pile, which is held in place until the refreezing soil grips it. Satisfactory depth is usually considered to be completely through the active area and half that depth again in the

permafrost. Usually the pile has an enlarged section on the bottom end. This is held rigidly in the refrozen permafrost and prevents any subsequent heaving through recurring seasonal frost action in the active area.

To summarize, soil investigation of any area in the permafrost zone must be done thoroughly prior to foundation design. By moving the proposed site of a building a few hundred yards, it may be possible to overcome many difficulties due to unequal settlement. It is essential that the building be carried on soils of equal bearing value, as free as possible from surface or underground ice conditions.

In the North, because of the very short summer and limited transportation facilities, a careful schedule is essential to obtain the desired results at reasonable cost. Preliminary reconnaissance should be finished by the autumn preceding proposed construction. Bulky material may be brought by tractor train over a winter road, although depending on location, barge transportation in summer is usually cheaper. Often foundation material can be shipped the previous fall, so that some construction can begin before the spring break-up. Design and material orders should be completed in the early winter to be ready for spring shipment. Careful timing is necessary to avoid construction delays due to shortages. All exterior work should be finished during the summer season, and interior work left for completion during late fall and winter. Outside construction in the North country in winter—with the temperature 40° to 50° below zero, a strong wind, and only a few hours of daylight—should be avoided except in extreme emergency.

The scope of this article is limited to two main types of soil—silts and permafrost. It is not to be assumed that these are the only types that will be encountered in construction of mine buildings. It is hoped that the methods outlined will help to solve other types of problems as they may arise.

Acknowledgment

The author wishes to thank the many engineers who have contributed their knowledge. He is especially indebted to R. F. Legget, Director of Building Research Division, National Research Council, Ottawa, Ont., for information and advice.

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Technical Note

Absorption Spectra of Some Sulphydryl Compounds

by Iwao Iwasaki and Strathmore R. B. Cooke

RECENTLY spectrophotometry has been reported to provide a convenient technique for the rapid and reproducible determination of xanthate concentration in pulp solutions,[1,2] and for a kinetic study of xanthate decomposition in acid solutions.[3] Since the application of this analytical technique is feasible for those compounds showing pronounced light absorption maxima in the near ultraviolet region, it was deemed advisable to investigate the absorption spectra of some of the organic compounds that are used in flotation.

It is known empirically that certain groups of atoms in an organic compound cause characteristic light absorption in the ultraviolet and near ultraviolet range, and the wavelengths and intensities of the corresponding absorption maxima are relatively independent of the nature of the remainder of the compound. The characteristic values of such groups, which are known as chromophores, are given in the literature.[4,5] According to this information, many of the sulphydryl compounds are expected to show absorption maxima in the near or long wavelength ultraviolet region, whereas the saturated fatty acids and the saturated alkylamines do not.

This article reports the absorption spectra of the six following types of sulphydryl compounds; mono-, di-(xanthate), and trithiocarbonates, dithiocarbamate, dithiophosphate (aerofloat), and mercaptan. A Beckman DU quartz spectrophotometer was used to investigate the spectra in the wavelength region of 215 to 350mμ.

Materials: All the mono-, di-, and trithiocarbonates used in this investigation were prepared in the usual manner[6] from appropriate compounds obtained from Eastman Distillation Product Industries. The dithiocarbonates included the normal alkyl compounds from methyl to octyl inclusive, as well as the isopropyl, isobutyl, and isoamyl xanthates. Iodometric titration gave 99.7 and 99.5 pct purity for

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TN 440B. Manuscript, March 19, 1957.

the ethyl and amyl xanthates respectively. The purified products were stored in vacuum in a refrigerator. Sodium diethyldithiocarbamate and propyl mercaptan, obtained from Eastman Distillation Product Industries, were used without further purification. Sodium diethyl dithiophosphate with a reported purity of 99+ pct was supplied by American Cyanamid Co. Demineralized water containing less than 0.1 ppm of salts as NaCl equivalent was used as the solvent throughout.

Experimental: The absorption spectra of the aqueous solutions of the above mentioned sulphydryl compounds, excepting mercaptan, are shown in Fig. 1, and data on the absorption maxima are summarized in Table I. In the wavelength range of 215 to 350mμ no absorption peak was observed for the mercaptan.

For the comparison of the relative intensities of the absorption maxima, the spectra have been normalized with respect to their optical densities* by employing their molar extinction coefficients, ε, defined as follows:

$$\epsilon = \frac{d}{cl}$$

in which d is the optical density, c is the concentration in mols per liter and l is the length of the light path of the absorption cell in centimeters.

* The terms *optical density* and *molar extinction coefficient* are equivalent to absorbance and molar absorbancy index as defined by Mellon.[8]

For the dithiocarbonates, irrespective of chain length, two absorption maxima were observed, one at 301mμ, the other at approximately 226mμ. These absorption peaks would correspond to the reported values of the chromophores $C = S$ at 330mμ[4] and $S - H$ at 227mμ.[5] The molar extinction coefficient of the 301mμ peak remained constant at 17,500 for all the xanthates tested, whereas the 226mμ peak showed a gradual increase in wavelength from 225 to 227mμ and in the extinction coefficient from 8500 to 9500 as the number of carbons in the hydrocarbon chain increased from 1 to 8.

Table I. Absorption Maxima of Some Sulphydryl Compounds in the 215 to 350-mμ Wavelength

Compounds	n	Absorption Peak, mμ	Slit Width, Mm	ε (Molar Extinction Coefficient)
Monothiocarbonate				
$C_nH_{2n+1}OCOSK$	3	222	0.440	12,400
Dithiocarbonate	1 ~ 8	301	0.360	17,500
$C_nH_{2n+1}OCSSK$ (xanthate)	iso-, 3, 4, 5	226	0.560	8,500-9,500
Trithiocarbonate		~333	0.340	>16,700
$C_nH_{2n+1}SCSSK$	3	~303	0.360	>13,600
		~235	0.510	>5,200
Dithiocarbamate				
$(C_nH_{2n+1})_2NCSSNa$	2	282.5	0.390	10,500
		257.5	0.420	10,700
Dithiophosphate				
$(C_nH_{2n+1}O)_2PSSNa$ (aerofloat)	2	227	0.560	3,700
Mercaptan				
$C_nH_{2n+1}SH$	3	No peak	—	—

Since an absorption peak characterizes a certain chromophore in a compound, an unstable reading of the optical density at that absorption maximum would indicate a change in the molecular structure by decomposition or by transformation. The thiocarbonates and the thiocarbamate were found to be unstable in acid solution, but all except the trithiocarbonate could be made stable by addition of excess alkali. The trithiocarbonate was not stabilized by adjusting the pH through the range of 3 to 12; hence the approximate shape of the absorption curve was determined at pH 11.5 and O°C, under which conditions decomposition seemed slowest. Thus the molar extinction coefficients for the trithiocarbonate are expected to be greater than the values reported in Table I.

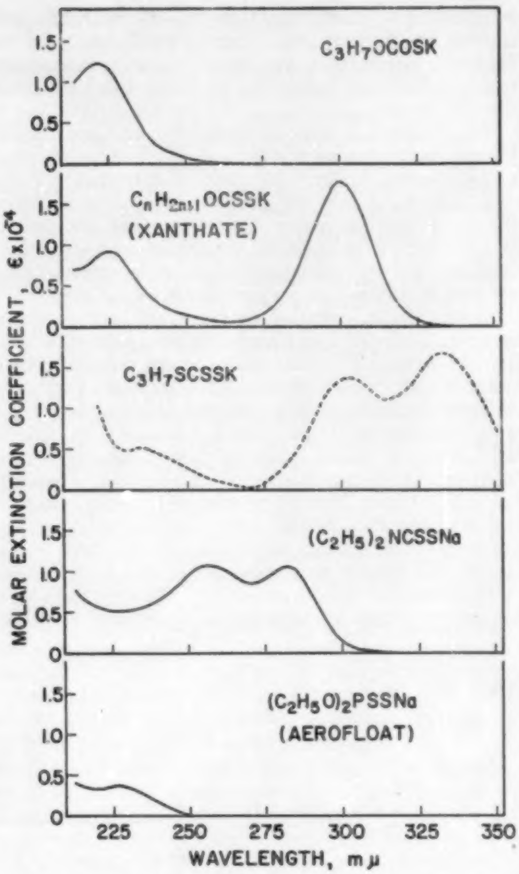

Fig. 1—Absorption spectra of some sulphydryl compounds.

The thiophosphate, unlike the other thiocompounds investigated, was stable over a wide pH range; in fact, no appreciable decomposition was noted even as low as pH 1.5, thus confirming the observation made by Rietz,[7] using the potentiometric titration method, that aerofloat is stable in acid solutions. This is in contrast with the case of the xanthates, where decomposition occurs very rapidly in acid solutions. For xanthates the spectrophotometric method has been shown to have an advantage over other methods in the study of the decomposition rate.[3]

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News of . . . Society Institute Profession

Preparations Progress for Engineering Center

Col. Davies Becomes Coordinator for New Engineering Center

Col. Clarence E. Davies, Secretary of ASME, has been named as Building Coordinator of the new United Engineering Center to be erected on United Nations Plaza between 47th and 48th Sts.

Shortly after his appointment was announced, Colonel Davies sailed for Europe. During his stay abroad, he had an opportunity to extend an invitation to representatives of 13 European engineering societies to share facilities in the new center. He visited engineering groups in Austria, Belgium, Denmark, Finland, France, Germany, Holland, Italy, Norway, Sweden, Switzerland, and the United Kingdom.

In announcing Col. Davies' appointment, Walter J. Barrett, president, UET, stated,

> "Since the Trustees' purchase of the site, plans have been under consideration to use the center to broaden the usefulness of the associated societies. Recognizing that the engineering profession is international in scope, the Trustees have anticipated the need for facilities to permit an even freer and more continuous interchange of engineering knowledge at a world communications center. Colonel Davies' trip to our colleagues in Western Europe is occasioned by a wish to share with them our plans for the new center and to invite them to adopt our facilities as a contact point in the United States."

Representatives of the engineering societies of Western Europe and the U. S. will meet during the week of Apr. 28, 1958, in New York, at which time the representatives are expected to take formal action on the invitation.

> "To the best of our knowledge," Colonel Davies stated, "this is the first time in the history of the profession that the expansion of world markets has necessitated long-range planning by our profession to keep abreast of industrial and commercial demands on an international basis. With the tremendously accelerated rate of development and technological and scientific progress, we feel we should be failing our public trust by not anticipating one of our primary functions as a world communications center for the engineering profession."

O. B. Schier, accompanied Col. Davies on his trip to Europe. Mr. Schier will become Secretary of ASME later this year, succeeding Mr. Davies, who is retiring. Colonel Davies will devote the major share of his time in the next few years to plans for the development and construction of the new United Engineering Center.

Kelly to Head Fund Drive for UET Center

Mervin J. Kelly, president, Bell Telephone Laboratories Inc., has been appointed General Chairman of the Business and Industry Campaign for the new $10,000,000 United Engineering Center, it was announced recently by Walter J. Barrett, president of UET. The United Engineering Center is to be constructed on United Nations Plaza between 47th and 48th Sts.

Dr. Kelly is one of the nation's distinguished scientists, with broad experience in directing research and development programs for Bell Telephone Laboratories, and for military projects undertaken by Bell Labs for the Armed Forces. He has served on many public assignments in Washington, D. C., particularly with the AEC, Dept. of Commerce, and the Dept. of Defense. For his service he has received the Air Force Exceptional Service Award and the 1953 Trophy of the Air Force Assn., awarded for "distinguished service to air power in the field of science," among many other honors.

The holder of a Presidential Certificate of Merit for his contributions during World War II, Dr. Kelly is a member of many philanthropic organizations, among which are those devoted to science, such as the National Academy of Sciences and the Swedish Royal Academy of Sciences. He is a life member of the Alfred P. Sloan Foundation Inc. and is a trustee and member of the Corporation of Atoms for Peace Awards Inc.

MERVIN J. KELLY

A graduate of the Missouri School of Mines and Metallurgy, Dr. Kelly received a Ph.D. degree from the University of Chicago in 1918, the year in which he began his career with the Bell System as a research physicist. He had served as director of research and executive vice president before becoming President of Bell Telephone Laboratories in 1951.

The campaign for funds for construction of the new Engineering Center will begin late this year, Dr. Kelly has announced. The initial efforts of the committee will be directed toward those businesses and industries which are most dependent upon the technologies represented

(Continued on page 1270)

Kelly *(Continued from page 1269)*

by the engineering societies. Members of the five major engineering societies, ASCE, AIME, ASME, AIEE, and AIChE, are well represented in those businesses and industries from which funds will be solicited. A total of over 184,000 engineers are included in the membership of these five societies. In addition to the five major societies, 15 other American technological societies have been invited to make their headquarters in the new center.

When Mr. Barrett announced the appointment of Dr. Kelly, he stated,

> "The present Engineering Societies Building at 29 W. 39th St. is today completely inadequate. Membership growth has multiplied many times during the past half-century that the present building has served as headquarters. Present space requirements of associated societies are twice the square footage available in the old building. Our need is urgent and acute and is underlined by the inevitability of future growth."

Readers of MINING ENGINEERING first saw a sketch of the proposed location and the announcement of purchase of the site in the September issue, page 969. MINING ENGINEERING will carry further news of the new United Engineering Center as it is released.

SME Technical Program Takes Shape For February AIME Meeting

The technical program for the Society of Mining Engineers' part in the AIME Annual Meeting to be held in New York, Feb. 16 to 20, 1958, is taking shape rapidly, according to Gill Montgomery, who is acting as Program Coordinator for SME. Division Program Chairmen are George L. Judy, Coal; T. E. Gillingham, Jr., Ind MD; R. H. Feierabend, MGGD; and N. Arbiter, MBD.

Coal Division

In addition to a symposium on bumps in coal mines and two sessions devoted to preparation of coal, the Coal Division plans four additional sessions. Some of the subjects to be covered are electronic controls and television monitoring around the coal mine, communication and mine lighting, a comparison of costs (installation and operation) for hoists vs slopes, and rock mechanics. Among the operational techniques to be discussed will be pumping coal through a pipeline, roof bolting in Kentucky mines, mining methods at the Thompson Creek Coal Co., Carbondale, Col., use of alternating current under ground, and safety precautions in opening a new coal mine.

Such other diversified subjects as pre-employment testing, ventilation of faces with continuous miners using auxiliary blowers, cementation of mine roof, and mine safety will be discussed. Probably included in these sessions will be discussions of the Joy microdyne dust collector as applied to coal dryers, industrial engineering, and dust control counter.

Industrial Minerals

IndMD is planning five sessions during the meeting, one of which will be a joint session with MGGD and one of which will be a joint session with MBD. The MGG-IndMD joint session will be on titanium raw materials, and the MBD-IndMD session will probably be on the subject of nonmetallic mineral dressing. The Division is planning an industrial water session to cover water and mining operations, water problems in the zinc district of southern Wisconsin, water problems in the Steep Rock Lake iron mine district of Canada, and one dealing with legal problems relating to water use in the eastern portions of the United States. At other IndMD sessions, there will discussions of uranium, monazite, and beryllium.

Minerals Beneficiation

MBD is planning eight sessions in addition to joint sessions with the Extractive Metallurgy Division and IndMD. The first of eight sessions will deal with concentration—the Pima concentrator, relation of magnetic susceptibility to mineral composition, distribution curves for heavy medium separation of iron ores, and flotation of manganese oxides by selective flocculation.

Theory of concentration processes will be discussed at a second session. Some of the topics planned are: mechanism of flocculent absorption on clay minerals, solubility of some metal ethyl xanthates, effective iron oxide slime coatings on silica flotation, and correlation of contact angle, adsorption density, zeta potential, and flotation rate.

New design has proven to be a favorite topic in recent years. This year's session will cover design problems in the taconite industry, seismic design for modern mills, comparison of 2300 and 4160-v circuits for large motors, and optimum applications of motor and speed reducers for conveyors.

A joint session is planned with the Iron and Steel Division on pyrolysis and agglomeration. Among the subjects to be discussed are fluosolids roasting of sulfides for recovery of copper, iron, and sulphur; beneficiation of low-grade iron ores by direct reduction; treatment of high-grade iron ores for production of metallic iron; and grate kiln process for pelletizing magnetite concentrates.

The history of magnetic separator development, dry magnetic cobbing separations, wet magnetic separators in taconite plants, and magnetic separation and media recovery, and other specialized fields will be some of the subjects covered in the Symposium on Magnetic Separation.

The Extracted Metallurgy Division and MBD are planning a joint ses-

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ROCK IN THE BOX

News of M.G.G. Division

We all realize that the success of any AIME effort is a direct function of our expanding active membership. AIME continually plans for increasing our membership rolls to include the many qualified individuals who should be a part of our organization. This works in many ways—through an all-Institute committee, Society committees, Division committees, and most importantly, through the Local Sections.

The MGG Division presently has three membership committees—one each for Mining, Geology, and Geophysics. The chairmen for this important work are presented below. We also have a representative on the Society of Mining Engineers Membership Committee. This year it is Dean La Grange.

It is rather difficult, and perhaps impossible, for a Subdivision membership committee—for instance Geophysics—to effectively cover membership problems throughout all the AIME Sections. At a recent MGG Executive Committee meeting we adopted the following policy as a means of organizing effective MGG membership activities. Dean La Grange has been asked to act as an overall MGG membership coordinator. He is to work with the three individual committee chairmen and through them recruit one MGG committeeman in each AIME Section that has some of our membership. We are suggesting that this committeeman consult with the Section chairmen requesting that he be a part of the Section's membership committee. This should take MGG membership activities down to the grass roots.

Our percentage of new memberships in the past few years has been low and we are in hopes that this may stimulate more activity. Incidentally, this plan will *tie in* with proposed changes in the new By-laws, as we will have one Division Membership Committee to concentrate on all those interested in mining and exploration.

The committee is counting on the enthusiasm of those named as Local Section membership representatives. Even better, if you would like to volunteer for membership work at the Section level write to:

Dean La Grange
1823 E. Superior St.
Duluth 12, Minn.

—*C. L. Wilson*

MEMBERSHIP COMMITTEE MEN


D. LA GRANGE


R. P. SATTERLEY


P. C. HENSHAW


W. E. HEINRICHS, JR.

Dean La Grange, *MGG representative on the SME Membership Committee,* is chief applications engineer for Eimco Corp. and is manager of the Duluth branch of the company. Born in Canon City, Colo., Mr. La Grange graduated from Colorado University in 1922. He began his professional career as a junior engineer with the Ray Consolidated Copper Co., Ray, Ariz., which later became part of Kennecott Copper. During his years with Ray and later Kennecott, Mr. La Grange was, successively, mine foreman, construction engineer, chief engineer, and superintendent of mines. He assumed his present position with Eimco in 1948. He has served on the AIME block caving mining subcommittee and the District 5 membership committee.

R. P. Satterley, *Mining Subdivision Membership Chairman,* is general manager of ore mines and vice president and general manager of Caland Ore Co. Ltd., Ishpeming, Mich., an Inland Steel Co. subsidiary. A graduate of Michigan College of Mines and Technology in 1925 with B.S. and E.M. degrees, he was born in Hubbell, Mich., and began his career with Inland Steel after graduation. Mr. Satterley has been engineer, chief engineer, mine superintendent, superintendent of Menominee Range, assistant and general superintendent, and manager of ore mines. He is a director of Pacific Isle Mining Co., a director of Miners' First National Bank in Ishpeming, director of Mather Inn, is president of the board of trustees of F. A. Bell Memorial Hospital, and is a trustee of the Presbyterian Church in Ishpeming.

Paul C. Henshaw, *Geology Subdivision Membership Chairman,* is assistant to the president of Homestake Mining Co., San Francisco. He was born in Rye, N. Y., and attended Harvard University and California Institute of Technology, receiving A.B., M.S., and Ph.D. degrees. He joined Cerro de Pasco Corp. in 1940 as geologist at the Morococha Mine in Peru, later becoming head geologist of the division.

Walter E. Heinrichs, Jr., *Geophysics Subdivision Membership Chairman,* is manager of Minerals Exploration Co., Tucson. Born in Superior, Ariz., he was brought up in mining camps in the western U. S. and the Philippines. He graduated from Colorado School of Mines in 1940 as a geological engineer. In 1955 Mr. Heinrichs received the School's initial Van Diest Award for outstanding work during the first 15 years following graduation. His first jobs were with National Geophysical Co., Dallas, and Seismograph Service Corp., Tulsa. After a two-year term in the U. S. Navy, he became assistant chief geophysicist with the U. S. Bureau of Reclamation, Denver. Mr. Heinrichs was, successively, assistant chief geophysicist, Newmont Mining Corp., and acting manager of mining exploration, United Geophysical Co. and Pima Mining Co., Tucson, before he joined Minerals Exploration Co. A member of AIME since 1951, he was co-recipient of the Robert Peele Memorial Award in 1955. He is a member of The Soc. of Exploration Geophysicists, Arizona Geological Soc., and Colorado and Arizona Professional Engineers.

Annual Meeting

(Continued from page 1270)

sion on hydrometallurgy. Two papers dealing with solvent extraction will cover high purity vanadium pentoxide at Climax Uranium Co. and the uranium from sulfate solutions. Other papers will cover resin-in-pulp process at Mines Development Inc., and preparation of reaction-grade uranium tetrafluoride from ores.

A crushing and grinding session will cover radiotracer techniques for studying grinding ball wear, soft and hard ball phenomena at Climax, comparison of one and two-stage grinding at Homestake, and grinding circuit of Farraday Mines Ltd.

A final session will cover developments in materials handling, operating control, and dewatering. Some of the subjects to be covered in this session are continuous stream analyzers, automatic weighing and rationing of solids, developments in continuous weighing of bulk solids, and hydraulic solids metering. Also to be discussed will be bulk solids lifting by bucket elevator, gamma ray gages in beneficiation plants, continuous pulp density and thickening, and applications of the horizontal type filter.

MGGD

The Mining Subdivision is planning to hold four sessions in addition to an all-MGGD session similar to that held last year. The open pit mining session will cover recent developments in the open pit and haulage facilities at Pima Mine, general aspects of the Nicaro nickel operation, practices at Jones & Laughlin Benson Mines, and a general study of open pit haulage.

A public relations and safety session planned for this year's meeting will touch upon increased production and better safety through communications and electronics; fire prevention, fire fighting, and pre-emergency organization; and safety in the uranium industry. Part of the same session will be a symposium on safety covering the industry point of view, USBM's view, and the view of the U. S. Public Health Dept.

A mining session will cover the use of ammonium nitrate blasting by a panel-type discussion presentation. Use of conveyor belts in block caving at Miami Copper and concrete ground support in block caving at Kelly Mine, Butte, Mont., will also be covered at this session. Probably included will be a paper on use of chain conveyors in block caving. A Canadian and Latin American session will probably include a paper on the Black Lake Asbestos Mine of the American Smelting and Refining Co. at Black Lake, Quebec.

A general mining session will cover such diversified topics as rock mechanics, lime stone mining operation of Foote Mineral Co., blasting vibrations—cause and effect—a movie supplied by Hercules Powder Co., and at least one general mining paper.

Geophysics

In addition to participation in the all-MGGD session, the Geophysics Subdivision is planning to hold three sessions. The first session will cover new exploration techniques, including rapid field methods for calorimetric determination of nickel for use in geochemical prospecting, tap and sample site determination of tracers of mercury in soils and rocks, a nuclear detector for beryllium minerals, hydrogeochemical exploration for uranium, and a rapid field test for copper in soils and sediments.

A second session on new exploration techniques will probably cover the airborne gravity radiometer, the induced polarization method, induced polarization in pyrite-bearing sandstone, airborne radioactivity surveying as a geologic mapping tool, meteorological influence on radon concentration in drill holes, and an open forum on new geophysical and geochemical exploration techniques.

To follow up the sessions on new techniques, the Subdivision is planning a session on actual exploration case histories. Probable topics to be covered include magnetic prospec-

ting for iron in Nevada, discovery of the Clearwater Stream deposit in New Brunswick, general prospecting for base metals, and specific base metal exploration in the clay belt of Ontario. Also included among the case histories will be the effect of soil contamination on geochemical prospecting in the Coeur d'Alene district, Shoshone County, Idaho.

As final details for the technical program are settled, they will be reported in forthcoming issues of MINING ENGINEERING.

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► Nominating Committee of the Council of Economics of AIME announces the following nominations for offices in 1958: Chairman, Franz R. Dykstra; Vice Chairman, W. Keith Buck and Sheldon P. Wimpfen; Executive Committee Members, W. J. Harris, Jr., and Paul Shultz; and Secretary-Treasurer, A. L. Lindley, Jr.

Mining Symposium To Be Held in Duluth

The University of Minnesota is sponsoring its nineteenth annual Mining Engineering Symposium in Duluth on Jan. 14 and 15, 1958. The Meeting is in conjunction with the annual meeting of the AIME Minnesota Section on Monday, January 13. Headquarters for both meetings will be the Hotel Duluth.

The program will cover a variety of topics of interest to Mining Engineers. Some of these include: handling of intermediate ores (scrubbing and screening); design and operation of surge piles, ore surge bins, stockpiles, and tailing sites; open pit operations; trucks and shovels; tires for trucks and off-the-road equipment; and drilling and blasting. Discussions of drilling and blasting will be aimed particularly at rotary, auger, and churn and down-the-hole drills. There will be a discussion of further recent experience with new explosives and with patterns of blasting.

The University's Symposium will begin on Tuesday morning, January 14, and will conclude at noon on January 15. The Symposium is being sponsored by the Center for Continuation Study of the University of Minnesota.

ENGINEER*

"EJC's Report on What's Happening in Engineering"

*A Periodic Newsletter from Engineers Joint Council • 29 W. 39th Street, New York 18, N.Y.

The General Assembly

The General Assembly, Thursday-Friday, October 24 to 25, New York Hotel Statler comprised the 25th Annual Meeting of ECPD and 4th EJC Assembly. Subjects covered were attitudes of engineers in industry and government—their implications to management; the community college and technological education; the place of the engineer in industrial management; new dimensions in post-graduate education for the young engineer. Participants included; Hugh L. Dryden, director, National Advisory Committee for Aeronautics; Joseph Coleman, personnel consultant to the Air Force; E. K. Fretwell, Jr., assistant commissioner for higher education of New York; Otto Klitgord, president of N. Y. City Community College; William E. Mullestein, Lukens Steel Co.; Harry Krieger, Radio Corp. of America; Frank W. Miller, Yarnall-Waring Co.; Paul Hemke, dean, Rensselaer Polytechnic Institute; S. B. Ingram, Bell Telephone Laboratories; R. W. Rawson, Fansteel Metallurgical Corp. Luncheon speakers were: Thursday, Thorndike Saville, dean of engineering, New York University; Friday, Dana Young, dean of engineering, Yale University. Clarence E. Davis, secretary ASME, was the Silver Anniversary Dinner speaker.

United Engineering Center

Entire block front on west side of first Ave., between 47th and 48th Sts., New York, was purchased by United Engineering Trustees Inc. for building to replace 29 W. 39th St. Center built in 1906. This section of First Ave. is known as United Nations Plaza. UET established in 1904 is the corporation in which five national societies (ASME, AIME, ASCE, AIEE, AIChE) will be associated in developing property.

Nuclear Congress 1958

Mar. 17 to 21, 1958, International Amphitheater, Chicago—headquarters hotel: Palmer House. Comprises 4th Nuclear Engineering and Science Conference; 4th International Atomic Exposition; 6th Hot Laboratories and Equipment Conference; 6th Atomic Energy in Industry Conference. Sponsorship to date: 30 national groups; overwhelming number of papers already submitted. Advance program to be published Nov. 15, 1957. For information, address Congress Manager, AIChE, 25 West 45th St., New York City, or your own Society secretary. EJC coordinates. Congress theme is *Industrializing the Atom* and newly declassified information will be made public for the first time.

Water Policy Report

EJC 1957 Restatement of Principles of a Sound National Water Policy—updating 1951 report—on *best seller list* with more than 5000 copies now distributed to industry, government, and education. Still available from EJC, 29 W. 39th St., New York 18, N. Y., at 25¢ a copy. Bulk discount available.

Educational Conference

October 31, November 1 to 2, Edgewater Beach Hotel, Chicago. Sponsored by Engineering Manpower Commission of EJC; Scientific Manpower Commission; National Science Foundation; National Research Council local sponsors: Western Society of Engineers. Purpose: to update facts on *Engineering and Scientific Education—Foundation of National Strength.* Participants include Lee A. DuBridge, president of California Institute of Technology; M. H. Trytten, National Academy of Science; Gordon B. Carson, dean of engineering, Ohio State University; J. S. Nicholas, Dept. of Zoology, Yale; W. C. Fels, president of Bennington College; W. H. Miernyk, Northwestern University; and others. Advanced programs available October 1 from Western Society of Engineers of EJC. Meeting will relate supply and quality of technical manpower to problems of higher education in engineering and science. Invitations being issued for special delegations to represent scientific and engineering societies, trade associations, educational groups, and government.

Mineral Industry Meetings

Nov. 14-15, Third Annual Symposium on Mining Research, Missouri School of Mines and Metallurgy and USBM, Rolla, Mo.

Feb. 6-7, 1958, California Governor's Industrial Safety Conference, 8th annual statewide meeting, including Mineral Extraction section, Fairmont Hotel, San Francisco.

• Publication date of 1957 for three books listed on pp. 1171 and 1173 of October MINING ENGINEERING were incorrect. The revised editions of **Hydrometallurgy of Base Metals** appeared in 1953, **Nonmetallic Minerals** in 1951, and **Mine Plant Design** in 1949

Recent personnel changes have been

constructed by **Theodore Chester**

Around the Sections

• The **Florida Section** held a dinner meeting on Sept. 9, 1957, at the Glass Diner Restaurant, Lakeland. Program or the evening featured a color film on the 1956 University of Florida *Gator* football season. The Section will be host for the first Annual Meeting of the Society of Mining Engineers and the Southeastern States Mining Conference, October 15 to 18, in Tampa.

• Rare earth alloys was the program subject for the September 13 meeting of the **St. Louis Section** and the Inorganic Div., American Chemical Soc. Howard E. Kremers, technical assistant to the president, Lindsay Chemical Co., was the guest speaker for the evening. He presented a comprehensive survey of the occurrence of rare earth and thorium ores, their industrial processing and process chemistry, and recent developments in the growth of the industry.

• John Isbell, of the Isbell Construction Co., outlined the activities of his company in mining and related fields at the September 20th meeting of the **Reno Subsection.** The meeting was held in the Fable Room, Mapes Hotel, Denver.

• The Anaconda Aluminum Co. was host to the **Montana Section** on September 21 at the Employees' Club in Columbia Falls, Mont. The Columbia Falls plant was host to the Section for the third consecutive year, and the meeting was a joint one with the company technical society. Walter G. Hay, superintendent, Anaconda Wire and Cable Co., Great Falls, presented a paper entitled *The Great Falls Aluminum Rod Mill.* H. G. Satterthwaite and J. F. Smith, in cooperation with Koehler Stout, the Section program chairman, extended Anaconda's invitation.

• A fall field trip was held by the **Lehigh Valley Section** on September 28. Members of the Section traveled to the White Hall Cement Manufacturing Co. in Cementon, Pa., to observe such modern cement techniques as quarrying, crushing, raw material handling and blending, preheating of raw material, burning, clinker cooling, and bulk cement handling, in their tour of the White Hall dry process cement plant. Buffet luncheon at Al Keiser's followed the plant tour and during lunch Section members had a chance to ask questions concerning plant operation.

• The September meeting of the **Colorado Plateau Section** was held at the Denver Hotel, Glenwood Springs, on September 28. This was a joint meeting with **MBD Section.** The technical session included the following papers: *Application of X-Ray Fluorescence to Process Control* by Robert McCune, Denver Research Institute; *Geology—Production and Related Features of the Rangely Oil Field, Rio Blanco County, Colorado,* by Robert L. Jackson, The California Co., *Development of Gilsonite Refining Project,* by John H. Henderson, American Gilsonite Co.; *Geology of the Oil Shale Deposit of the Southern Part of Piceance Creek Basin,* by Irvin T. Nielsen, Union Oil Co.; and *Union Oil—Oil Shale Project—Progress Report,* by John R. Pownall, Union Oil-Oil Shale plant. The afternoon technical session was followed by a cocktail party, dinner, and dancing. Section members also had a chance during the day to enjoy the swimming facilities in Glenwood.

• Members of the **St. Louis Section** enjoyed both field trips and a fish fry on October 11, when operators in the Illinois-Kentucky Fluorspar District were hosts to the Section. Members had a choice of four out of ten field trips. Among the six mines open to visitors were the Hill Ledford, the Oxford, and the Fredonia mines of Ozark-Mahoning in the Rock District on the east side of Harden County. In the same area are Mine No. 1 and the Crystal-Victory bedded mines of Minerva Oil Co. In Rosiclare, members of the Section had a chance to visit the Aluminum Co. of America mine. Also on the agenda for the field trip were four mills. In Rosiclare, field trippers had a choice of a visit to Alcoa's HMS-flotation mill or Ozark-Mahoning's all-flotation mill. At Cave in the Rock District, the Crystal, all-flotation mills of Minerva Oil Co. were open to visitors. A box lunch was provided to members of tal, HMS and flotation, and Plant No. the Section, courtesy of the mining companies sponsoring the field trips. The day's events wound up with a buffet fish fry at Cave in Rock State Park.

American Cyanamid Co. has completed a 16-mm sound and color film entitled *The Man in the Doorway.* **The film, produced as part of the 50th anniversary program of American Cyanamid, is a tribute to the chemical industry. Subject matter of the film ranges from agriculture and plastics to the vital fields of health and the fascinating story of antibiotics. Its theme is conservation—how chemistry helps protect this country's abundant but not unlimited resources—and presents a warning of the consequences of failing to conserve. Inquiries regarding information about the film should be addressed to Miss Norma Anderson, American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N. Y.**

You and Labor Law, **a two-part, 30-min. sound slidefilm in color has been completed by Transfilm. Part I shows the evolution of labor law philosophy and precepts, and part II shows present labor laws in action.**

The film highlights such events in labor history as the actions of the World War I Labor Board, the NRA, the Norris-LaGuardia Act, the Wagner Act, and the Taft-Hartley Law. In the second part of the film, action under the present laws is depicted. The film is available for sale through the Employers Labor Relations Information Committee Inc., 33 E. 48th St., New York 17, N. Y.

CIM Casebook Issued

S. F. Kelly, Chairman, and E. W. Westrick, co-chairmen of the CIM Committee for Casebook in Mining Geophysics, report that the volume, being issued in conjunction with the sixth Commonwealth Mining and Metallurgical Congress, will be of great interest to mining engineers, geologists, and geophysicists.

Entitled *Canadian Casebook of Mining and Engineering Geophysics in the Commonwealth,* the volume will be the first geophysics casebook devoted exclusively to mining and engineering (water supply problems and dam-site considerations). Committee chairman S. F. Kelly has been active in both AIME and CIM, having served for two years as AIME committeeman on cooperation with CIM.

SME Education Group

The Minerals Beneficiation Division has appointed T. G. Chapman, College of Mines, University of Arizona, Tucson, to serve on the Society of Mining Engineers Education Committee from the Division. Dean Chapman will pinch-hit for W. B. Stephenson, who is in Europe at this time.

PERSONALS

R. PERLEY

Richard H. Perley has been appointed vice president and general manager of Hycon Aerial Surveys Inc., Pasadena, Calif. Mr. Perley, who has been associated with Hycon for the past seven years, recently headed the Customer Services Div. **William H. Cook** has been appointed to the Scientific Advisory Board of the same company.

Recent personnel changes have been announced by Diamond Alkali Co.: **A. H. Ingley,** vice president-manufacturing for the last nine years, has been named senior vice president; **James A. Hughes,** treasurer, has been promoted to vice president-administration; **Donald S. Carmichael,** secretary, has been named to the additional post of general counsel; and **R. H. Armor,** assistant treasurer, succeeds Mr. Hughes as treasurer.

W. H. COOK

A new 100-lb pilot mill for uranium ore milling has been devised and constructed by **Theodore Chester Crawford** and **John Urban** in Albequerque, N. M. Mr. Urban, a mechanical engineer for A. E. Boyd Equipment Co., Albequerque, put the plant together from the verbal description supplied by Mr. Crawford. Mr. Crawford, who has been working for nearly a year under the auspices of Yucca Mining & Petroleum Co. Inc., Albequerque, had described a theoretical plan to Mr. Urban in an attempt to create a practical device that would carry uranium ore through the refining processes by electrolysis. The new mill was successfully demonstrated recently. Funds for its construction were provided by **Melvin E. Richards,** president, and other directors of Yucca Mining, for research for the benefit of the uranium industry.

Clifford A. Neros has been promoted to group leader in product development for Diamond Alkali Co. and **James L. Foster** to group leader in silicate research.

Elmer E. Kraig, formerly of the Smith Engineering Works, Milwaukee, is now working as chief engineer of the newly created Rock Products Engineering Dept. of Hewitt-Robins Inc., Glenbrook, Conn.

and president of St. Louis Coal Sales

steel producer accounts. Joseph H.

W. MOHR

William Mohr has been appointed works manager of the Pacific Coast Div. of the Colorado Fuel and Iron Corp. Mr. Mohr was wire mill superintendent prior to his appointment.

Richard E. Brandt, previously with Battelle Memorial Institute, Columbus, Ohio, has joined the research staff, Michigan Chemical Corp., St. Louis, Mich. **Charles R. Jacoby** is working with the same company on the engineering research staff. Mr. Jacoby was with Union Starch and Refining Co., Granite City, Ill.

Hans Neeb of Rossberg/marburg, Germany, is traveling in North America and the Far and Middle East. He had been associated with Acerias Paz Del Rio, S. A., Bogota, Colombia, in the mining department.

John S. Westrope, who had been a student in metallurgical engineering at Texas Western College, has taken a job as process engineer with Titanium Metals Corp. of America in Nevada.

Rex M. Chaney, former member of the Washington staff of United Press, has become director of public relations for the National Coal Assn. He has resigned his position as administrative assistant to Congressman Carl Albert of Oklahoma to work with the coal association in Washington, D. C.

J. B. Dennison has been elected as president of the Institution of Mining and Metallurgy, London, England, for 1958-1959. Mr. Dennison joined the Institution in 1919. He has held the office of vice president for the three sessions, 1953-1956. He is a consulting engineer for Johannesburg Consolidated Investment Co. Ltd., London.

Gregory S. DeVine has become a vice president of the Chesapeake and Ohio Railway in Cleveland. He was formerly executive vice president of Peabody Southern Coal Co.

Geneva Div., has been appointed to

and president of St. Louis Coal Sales Co. Mr. DeVine is president of the Midwest Coal Producers Inst. and a director of the Illinois Coal Traffic Bureau.

W. A. HALEY

W. A. Haley recently joined Caterpillar Tractor Co. as mining representative for the Sales Development Div. In his new position, Mr. Haley will specialize in metals market operation. He had been associated with USBM, Pittsburgh.

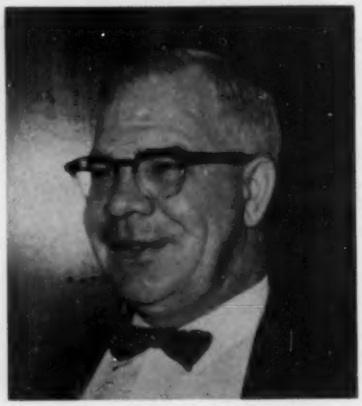
Mine Safety Appliances Co. has appointed **R. J. Fay** to the post of sales engineer for South Chicago steel producer accounts. **Joseph H. Helm** has been appointed sales engineer in the Milwaukee office of the same company.

Kenneth C. Towe, president of American Cyanamid Co. since 1952, has been elected to the new post of chairman of the board of directors. He is succeeded as president and chief executive of the company by **Wilbur G. Malcolm,** formerly vice president for marketing. At the same time, **Kenneth H. Klipstein,** a vice president, has been elected a director.

American Smelting and Refining Co. recently appointed **R. L. Rigsby,** Salt Lake City, accounting manager of Peru Copper Co., Chile; and **L. K. Nicholson** as accounting manager in Salt Lake City.

Alvin L. Krieg, public relations director for U. S. Steel Corp., is now president of Junior Achievement of Utah Inc.

A. Raymond Jordan has been appointed dean of the Graduate School at the Colorado School of Mines, Golden, Colo. The new graduate dean has been associated with the Denver Research Institute for the past five years, serving his last year as head of the physics division.



B. A. HANEY

Byron A. Haney has been appointed northwestern sales manager for Bucyrus-Erie Co. He took over responsibility for the sales of all Bucyrus-Erie products in Washington, Oregon, Idaho, and Montana, the Territory of Alaska, and the Yukon Territory. Mr. Haney is maintaining headquarters in Seattle.

William F. Darmitzel has been promoted to executive director of the New Mexico Mining Assn., succeeding **C. H. Murphey,** retired.

F. Ray Friedley, assistant comptroller, U. S. Steel Corp., Columbia-

Geneva Div., has been appointed to comptroller of the firm's Oliver Iron Mining Div., Duluth.

Grey Bogden is now serving as industrial relations superviser for Kennecott's Magma and Arthur mills; **Dale Peterson** is in public relations at the firm's Garfield refinery; and **John J. Trant** is working as supervising auditor for Kennecott's comptroller's department.

Charles E. Prior has been named mining director and elected to the board of Western Gold & Uranium Inc., producers of uranium, silver, and other metals in Arizona and Utah. Mr. Prior has been a consulting mining engineer since 1956, and prior to that was associated for many years with American Smelting and Refining Co.

R. CALACETO

Ralph R. Calaceto has joined the Automotive Rubber Co. Inc. as manager and sales engineer of the Process Equipment Div. in New York. Mr. Calaceto formerly served 6½ years as project engineer with the Chemical Construction Corp. of New York.

Mr. and Mrs. James A. Barr have returned home to Mt. Pleasant, Tenn., from Rome, Italy, where Mr. Barr was on a minerals economic mission for the International Bank For Reconstruction and Development (World Bank).

Jan Leja is now with the Dept. of Mining and Metallurgy, University of Alberta. Edgmonton, Albe., Canada, where he is serving as assistant professor of metallurgy. Dr. Leja was formerly with the Dept. of Colloid Science, University of Cambridge, England.

Robert M. McGeorge has been promoted to assistant manager for the Southwestern Dept. of the American Smelting & Refining Co., El Paso, Texas. Mr. McGeorge was

formerly ore buyer for the company's Garfield plant.

R. LORD

Southwestern Engineering Co. saluted metallurgical authority **Robert Lord** on his four decades of service with the company. Mr. Lord, who is head of SWECO's Metallurgical Laboratory, was presented the company's first 40-year service pin by **Robert P. Miller,** SWECO president.

W. Lunsford Long, president of Haile Mines Inc., New York, has become chairman of the board of directors of the company and its subsidiaries—Tungsten Mining Corp. and Manganese Inc. **William M. Weaver, Jr.,** has become president. Mr. Weaver is president of Frank Samuel & Co. Inc. of Philadelphia, ore importers since 1889, and now affiliated with Haile Mines.

Andre L. Brichant, who was formerly adviser to the State Planning Bureau in Djakarta, Indonesia, has now accepted appointment by the Government of Morocco as adviser to the Director of Mines, Ministry of National Economy, Rabat, Morocco.

A. BRICHANT

George G. Griswald, Jr., Butte, has been awarded honorary membership in the Montana Society of Engineers. Mr. Griswald, a member of the Mining Assn. of Montana, is a consulting metallurgist, author of technical papers, and developer of several flotation processes used in separating complex ores.

Frederick C. Kruger has been promoted to director of mining and exploration for International Minerals & Chemical Corp., Chicago. He joined the company in February of this year and since June had been acting head of the Mining and Exploration Dept.

Roy D. Haworth has terminated his association with the Wheelabrator Corp., Mishawaka, Ind., and is now sales manager for the Fargo Machine & Tool Co. in Detroit.

John W. Schausten has accepted a position as metallurgist for Cleveland-Cliffs Iron Co. He was formerly with Jones and Laughlin Steel in Pittsburgh.

Robert C. Bates is now working for Balboa Mining and Developing Co. in Grand Junction, Colo., as geologist and exploration engineer.

George R. Leland is now employed by Frontino Gold Mines Ltd. as assistant general manager.

George Robert Huebner has completed work for his degree and is now working for the International Nickel Co. of Canada Ltd., Levack, Ont., Canada.

M. M. Harcourt, former mine Superintendent for Haile Mines Inc., New York, has accepted a position with Round Mountain Gold Dredging Corp., Round Mountain, Nev., as resident engineer.

Howard H. Rice has been employed by the Silver Bell Unit of the American Smelting & Refining Co. in Silver Bell, Ariz. He had been associated with Neptune Gold Mining Co., Nicaragua.

George M. Marks, Jr. is now working as an engineer for the Industrial Heat Engineering Co. in Greenville, S. C.

Alex E. Nielson has been appointed mine foreman for the Cia Minera Asarco, Santa Barbara, Mexico. Mr. Nielson formerly served as mine superintendent for the Wah Chang Mining Corp.'s Lincoln Mine in Tempiute, Nev.

Russel H. Campbell has been reassigned from the U. S. Geological Survey, Denver, to its Menlo Park, Calif., headquarters after completing his work on the Survey's quadrangle mapping project in the Elk Ridge area of southeastern Utah.

James R. Miller has taken an administrative position with Ocean

Services Inc., San Francisco. Mr. Miller formerly worked in the engineering department of the Link-Belt Co., Chicago.

Merle H. Guise has returned to San Marino, Calif., after a five-month tour of Mexico.

Fred E. Johnson is now serving with United Air Lines as a flight engineer. Mr. Johnson was formerly associated with the Hanford Atomic Products operation of the General Electric Co. as an engineer.

Joel H. Teel, formerly mill superintendent of Darwin Mines of The Anaconda Co., Darwin, Calif., has been transferred to the company's Montana operations as assisting research engineer in the Metallurgical Research Dept.

Parke A. Hodges, vice president of Behre Dolbear & Co. Inc., attended the International Minerals Dressing Conference in Stockholm as representative of the Mining and Metallurgical Soc. of America. Mr. Hodges visited the iron mines of Northern Sweden and the potash mines of Western Germany while he was in Europe.

H. B. Humphrey, formerly a mining engineer with the U. S. Bureau of Mines, Health and Safety Div. has now retired after 29 years of service.

Sheldon H. Penn has terminated his employment with the Transcontinental Gas Pipe Line Corp. Mr. Penn is now working with the Ideal Cement Co. as a geological engineer in Ft. Collins, Colo.

Fred D. Waltman has resigned his position as general manager of Florida Manganese Inc. at Deming, N. M., to accept a position with United Western Minerals Co. of Santa Fe, N. M., where he will be in charge of all mining for that company.

L. R. Brown is no longer general mine foreman of the Morococha Div. of the Cerro de Pasco Corp., Peru. He has been transferred and promoted to the position of assistant superintendent of the Casapalca Div. of the company in Peru.

Carl Ludwig has been made chief engineer of the Engineered Products Div., Wellman Engineering Co., one of the manufacturing affiliates of McDowell Co. Inc., Cleveland. Mr. Ludwig has been with Wellman since 1956.

A. C. Sada has been promoted to the position of superintendent of the Uranium Plant for the Union Carbide Nuclear Co., Div. of Union Carbide Corp., Colo. He was formerly general superintendent for the company.

O. DAVILA

O. Davila is now in the United States with a special fellowship from the International Cooperation Administration and Corp. Minera de Bolivia to study tin slime treatment at the U. S. Bureau of Mines Station at Rolla, Mo. He will also attend some advance course at the Missouri School of Mines.

Howard L. Hartman, former associate professor and acting head of the Dept. of Mining Engineering at the Colorado School of Mines, has been appointed professor and head of the Dept. of Mining. Dr. Hartman replaces **Arnold W. Asman** who resigned to become product manager of mining equipment sales of the Robins Conveyor Div., Hewitt-Robins Inc., Stamford, Conn.

Javier Diaz Chavez has been promoted to mine foreman of the Cerro de Pasco Corp. operations in Peru. He was formerly assistant chief engineer in the engineering department. Mr. Chavez recently received an M. S. in mining engineering with a minor in geology at the University of Arizona, Tucson. His thesis subject was *Proposed Development of a South American Copper Deposit for Mining Operations.*

J. J. Fitzpatrick graduated recently from the Royal School of Mines, London, and is now working in Falconbridge, Ont., Canada, for Falconbridge Nickel Mines Ltd. He is participating there in the graduate training program sponsored by the Ontario Mining Assn.

William M. Traver of Denver, U. S. Bureau of Mines mining engineer who died last March, has been honored posthumously with the Dept. of the Interior's Meritorious Service Award and Silver Medal. "His planning and expert direction of mineral development in remote virtually inaccessible mountainous areas of Colorado were particularly notable," the citation read. The award carries with it a lifetime pass to all the national parks for his widow, Mrs. Blanche R. Traver, who resides at the family home in Denver.

J. W. THIGPEN

Jack W. Thigpen, former administrative assistant at Herb J. Hawthorne Inc., Houston, has been promoted to the position of sales manager.

Thomas E. Ban has terminated his employment with the Cleveland-Cliffs Iron Co. as research engineer and is now director of research for McDowell Co. Inc., Cleveland.

Edson R. Packer, formerly mill superintendent for Northern Peru Mining & Smelting Co., Chilete Unit, Peru, is now a metallurgist for The Anaconda Co., New Mexico operations, Grants, N. M.

Herbert E. Harper, chief geologist for the Hecla Mining Co. has moved his headquarters from Wallace, Idaho, to Spokane, where the company has opened a new exploration office.

William G. Saunders is now a metallurgist for Dow Mining Chemical Sales of the Dow Chemical Co. Prior to this position, he served as a senior concentrator metallurgist for the Cerro de Pasco Corp.

Henry B. Legget, consulting mining geologist and engineer, has been doing considerable work in Latin America, particularly in Mexico, since the curtailmen of mining operations in the Rocky Mountain area of the U. S.

Chester M. Peters, formerly a consulting engineer in Salt Lake City, is now working for the Behre Dolbear Co. as consulting geologist engineer. Mr. Peters recently completed a two-month examination trip to Nicaragua and a short trip to Chibougamau, Canada.

E. R. Palowitch has accepted the position of supervisory technologist for the Mining and Preparation Section of the U. S. Bureau of Mines, Pittsburgh. He formerly was assistant professor of mining engineering at West Virginia University, Morgantown, W. Va.

J. A. GRAHAM

James A. Graham has been promoted to manager of Mining Tool Sales for the Carmet Div. of Allegheny Ludlum Steel Corp. He was formerly in the sales department of the Detroit division that specializes in tungsten carbide products.

After completing an assignment in Pakistan, **John L. G. Weysser,** consulting mining engineer, visited Australia, where he viewed the mining operations of The Zinc Corp. at Broken Hill, New South Wales, and the brown coal open pit of the State Electricity Commission at Yallourn, Victoria. He also visited mining friends in Korea before returning to the U. S. and his home in Paxinos, Pa.

Richard D. Ellett, geologist with National Lead Co., has been in charge of an extensive exploration program for copper within the Northern Territory of Australia. The work is being conducted by National Lead.

Earl K. Nixon reports that he has spent several weeks in mineral investigation work in Brazil. Earlier this year Mr. Nixon had spent some time in Uganda.

Emil A. Kronquist, safety and personnel director, Michigan Ore Div., Jones & Laughlin Steel Corp., retired on September 1. A graduate of the University of Wisconsin in 1916, Mr. Kronquist began his professional career with The M. A. Hanna Co. in Duluth. He became geologist for Ford Motor Co., doing exploration for iron in Michigan, for other base metals—particularly lead—in Idaho, and work in Canada. Mr. Kronquist has been with J&L in Minnesota, Michigan, New York, New Jersey, and Ohio. His work for the company included geology, mine safety, and personnel. For about 12 years until his retirement, Mr. Kronquist had been with the J&L Tracy mine—from exploration to production.

OBITUARIES

Stanley Lincoln Arnot

An Appreciation By

Walter A. Stinson

Stanley Lincoln Arnot (Member 1941) consultant engineer for United States Lime Products Corp. died on January 18, 1957 in Sonora, Calif.

Mr. Arnot was born on Dec. 25, 1889 at Markleeville, Calif., of pioneer parents. He attended the public schools in Markleeville and Placerville, Calif., and studied at the University of California where he received a B.S. degree in mining engineering in 1941. After graduation he was employed at the North Star Mine, Grass Valley, Calif., as a mucker, time keeper, surveyors assistant, cyanide plant operator, and assayer. In 1915 he joined the staff of Plymouth Consolidated Gold Mines, Ltd., on the Mother Lode at Plymouth, Calif. At this time, Plymouth was one of the great mines in the world. From 1918-1920 he was chief engineer for Plymouth Consolidated Gold Mines, Ltd; Carson Hill Gold Mines, Inc. and Dutch-App Mines Co. It was during this period Mr. Arnot examined a group of scheelite claims near Mill City, Nev., reporting favorably thereon to Mr. William J. Loring. This group was developed into one of the great tungsten deposits of the United States, now operated by the Nevada-Massachusetts Mining Co. From 1920-1925 he was general superintendent of Plymouth Consolidated. Mr. Arnot was associated with the firm of Hamilton, Beauchamp & Woodworth from 1925-1927 in the examination and operations of mines and in land-condemnation studies for the Oakdale Irrigation District and the East Bay Municipal Utility District prior to development of their water resources in the Sierra Nevadas.

Late in 1927, Mr. Arnot joined U. S. Lime Products Corp. During this period 1927-1956 he served this organization as superintendent at its operations Sloan, Nev.; resident manager at Sonora, Calif.; and subsequently as consulting engineer.

He was married to the former Juanita Alice Kyburz of Placerville, Calif., on Sept. 9, 1916. In addition to his widow he is survived by a daughter, Mrs. Frank Pursel, of Piedmont, Calif.

He was a member of the Las Vegas Rotary Club, the Sonora Lions Club, and the Commonwealth Club of San Francisco.

Stanley Lincoln Arnot was keenly aware of the civic responsibilities of a good citizen and, as an individual and a member of many civic organizations contributed much to the betterment of the communities in which he lived. To those of us who knew his acquaintance, his companionship and friendship, our loss will be tempered by the remembrance of his great interest in helping young engineers, his rich sense of humor, his personal integrity, and his professional competence.

Algernon N. Borszich (Member 1956) is recently deceased. Born in Lakeview, South Dakota on Mar. 16, 1930, he attended the South Dakota School of Mines and Technology. His home address was in Mission, S. D.

Charles K. Leith (Legion of Honor Member 1903) died recently. Mr. Leith was born Jan. 20, 1875 at Trempealean, Wisc. He received his B.S. degree at the University of Wisconsin in 1897 and his Ph.D. in 1901. His career included the post of professor of Geology at the University of Wisconsin, Advisor to the Materials Division of the U. S. War Production Board, Member of the Business Advisory Council to the Dept. of Commerce and was the author of Monograph and Map of Mesabi Iron Range for U. S. Geol. Survey.

Lesley McCreath (Legion of Honor Member 1902) died Aug. 18, 1957. Born in Harrisburg, Pa. on Feb. 15, 1881, he was graduated from Harrisburg Academy in 1898 and in 1901, from Sheffield Scientific School of Yale University. Mr. McCreath, an associate of the firm of Andrew S. McCreath & Son was a member of the AIME for 55 years. His father, the late Andrew S. McCreath was also a Legion of Honor member.

Edward L. Ralston (Member 1939) passed away on July 9, 1957. Born in Montana on Nov. 27, 1886, he was educated at the Montana School of Mines and the University of Utah. Mr. Ralston was manager of Mines for The Glidden Co. of Redding, Calif.

Eugene Staritzky (Member 1945) died on May 15, 1957. He was born on Oct. 26, 1902 in St. Petersburg, Russia and studied mining engineering at the Technische Hochschule in Berlin, 1922-25. From 1925 to 1927 he studied at the Colorado School of Mines and received the degree of Metallurgical Engineer. From 1927 to 1935 he conducted research and development for the Dorr Co. in New York and Westport, Conn. In 1935 he was appointed associate director of the Colorado School of Mines research laboratory at Golden. Since 1948 he was associated with the University of Calif., Los Alamos Scientific Laboratory, Los Alamos, N. M. Mr. Staritzky was the author of more than 60 publications in his field of the rarer and man-made elements.

James R. Russell (Member 1943) died Aug. 5, 1957 in St. Cloud, Fla. He was born in Middleport, Ohio on June 12, 1913 and was educated at the Case School of Applied Science and Ohio State University where he studied mining engineering.

J. B. Tyrrell (Legion of Honor Member 1899) the noted Canadian geologist who predicted the presence of oil in Alberta a half-century before it was found, died Aug. 26, 1957 at his home in Toronto. Dr. Tyrrell's name became a byword in Canadian scientific circles when settlement in Western Canada was in the pioneer stage. So accurate was his work in surveys of the area that the saying "as good as Tyrrell" was coined. He made important mineral findings one after another, traveling in previously uncharted parts of the country with nothing more than his geologists hammer. In his nintieth year, Dr. Tyrrell was awarded the Woolaston Medal, the highest honor of the Royal Geological Society. In 1954 he received the Engineer's Medal just before he retired as president of Kirkland Lake Mining Co. The Grand Old Man of Mining also received the Back Award of the Royal Geographical Society, the Murchison Medal of the American Geological Society, and the Legion of Honor from the AIME. He also was awarded the Flavelle Medal of the Royal Society of Canada. Surviving are a daughter, Mrs. J. A. Dalton, and two sons, George and T. A. C. Tyrrell, Ontario's Deputy Minister of Planning and Development.

George F. Zoffman (Member 1920) passed away on June 5, 1957. Mr. Zoffman was born June 4, 1880 in Calif. and graduated from Stanford University in 1907 with an A.B. degree. Prior to his death Mr. Zoffman was president of Duval Sulpur & Potash Co. in Houston, Texas.

Necrology

Date Elected	Name	Date of Death
1902	A. B. Emery Legion of Honor	July 26, 1957
1921	Lincoln Johnson	Sept. 2, 1957
1949	F. V. Richard	Sept. 5, 1957
1927	A. Gonzales Soto	Mar. 2, 1957
1947	Will M. Traver	March 1957

MEMBERSHIP

Proposed for Membership
Society of Mining Engineers of AIME

Total AIME membership on Sept. 30, 1957, was 28,317; in addition 3,155 Student Members were enrolled.

ADMISSIONS COMMITTEE

Robert Grogan, Chairman; Frank Ayer, Jack Bonardi, A. C. Brinker, Jack B. Graham, F. A. McGonigle, F. W. McQuiston, Jr., G. R. Spindler, L. P. Warriner.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Continued on Page 1286

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Coming Events

Oct. 30-Nov. 1, AIME Rocky Mountain Minerals Conference, Denver.

Nov. 8, AIME St. Louis Section; speaker: Andrew Robertson; subject: *Economics and Practice at Chibougamou Mining District and Chicoutimi Smelter;* Hotel York, St. Louis.

Nov. 8, AIME Pennsylvania-Anthracite Section, fall technical meeting, Wilkes-Barre, Pa.

Nov. 8-9, AIME Central Appalachian Section, West Virginia Mining Inst., joint meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

Nov. 11-14, Society of Exploration Geophysicists, 27th annual meeting, Statler-Hilton Hotel, Dallas.

Nov. 21, AIME Utah Section, panel discussion: *Mining Industry: New Methods, Machines, and Materials;* moderator—Norman L. Weiss; panel—James D. Moore, Joseph Rosenblatt, P. K. Richardson, Harvey Mathews. Salt Lake City.

Dec. 12, AIME Utah Section, *The Engineering Aspects of American Gilsonite Developments* by Roy E. Nelson; Salt Lake City.

Dec. 13, AIME St. Louis Section, ladies night; speaker: W. D. Shipton; subject: *Gems;* Hotel York, St. Louis.

Jan. 10, 1958, AIME St. Louis Section, joint meeting with AIChE St. Louis section; speaker: N. E. Berry; subject: *New Developments in Uranium Processing;* Hotel York, St. Louis.

Jan. 13, AIME Minnesota Section, annual meeting, Hotel Duluth, Duluth.

Jan. 14, 15, 19th Annual Mining Engineering Symposium, sponsored by University of Minnesota, in conjunction with AIME Minnesota Section, Hotel Duluth, Duluth.

Jan. 16, AIME Utah Section, panel discussion: *Industrial Engineering Practices in the Mineral Industries;* moderator—I. K. Hearn; Salt Lake City.

Feb. 16-20, AIME Annual Meeting, Hotels Statler and Sheraton-McAlpin, New York.

Mar. 27-29, AIME Pacific Southwest Conference, St. Francis Hotel, San Francisco.

Apr. 17-19, AIME Pacific Northwest Regional Conference, Spokane.

Apr. 25, AIME Pennsylvania-Anthracite Section, spring technical meeting, Hazelton, Pa.

May 24, AIME Colorado MBD Subsection, Broadmoor Hotel, Colorado Springs, Colo.

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